Design of Social Insurance Programs: Theory and Evidence

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The Faculty of Business, Economics and Informatics of the University of Zurich hereby authorizes the printing of this dissertation, without indicating an opinion of the views expressed in the work.

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Chapter 1

Dissertation Overview

This dissertation, "*Design of Social Insurance Programs: Theory and Evidence*", studies the optimal design of old-age pension and disability insurance programs. These are large and important social insurance programs. In 2015 OECD countries spent on average seven percent of GDP on old-age pensions (15.8 percent of total government expenditure) and one percent of GDP on disability pensions (2.2 percent of total government expenditure).[1] Aging societies and rising disability rates pose serious challenges for the financial stability of these programs and reforming these programs is on the political agenda in many countries. This dissertation aims to shed light on optimal policy design and reforms by connecting economic theory with empirical evidence. Chapter 2 studies welfare effects of old-age pension reforms and Chapters 3 and 4 analyze the effectiveness of different policy instruments in disability insurance programs.

In the theoretical parts of my dissertation I want to understand the key trade-offs in the design of these transfer programs and how these trade-offs can be quantified. In particular, the main goal of the theoretical sections is to relate these trade-offs to well identified reduced form estimates. In the empirical parts, I study how transfer programs affect individual behavior and government spending by exploiting rich administrative data and quasi-experimental variation in program rules. Based on the theoretical framework and the empirical estimates I then assess the welfare implications of different policy reforms. In designing any social insurance program, policy makers face a trade-off. A more generous social insurance program reduces the exposure to risk (insurance value) but might increase the distortionary costs of the program. To study and quantify this trade-off, I follow a "sufficient statistics" approach in all three chapters. The idea of this approach is to link formulas of optimal policy to empirically estimable quantities. The sufficient statistics approach is popular in the optimal unemployment insurance and optimal tax literature. A major contribution of this dissertation is to extend this approach to old-age pension and disability insurance programs. While there exists a rich literature that evaluates the labor supply and fiscal effects of reforms in disability insurance and old-age pension programs, the link between these empirical estimates to welfare consequences is missing so far.[2] This dissertation aims to provide this link.

Chapter 2 studies old-age pension reforms and is titled *"Welfare Effects of Pension Reforms"*. In almost all developed countries, policy makers have implemented pension reforms by increasing statutory retirement ages, lowering pension levels and/or adjusting pension formulas to address demographic change. The basic idea of pension reforms is to incentivize workers to delay their retirement, thus increasing the ratio of workers to pensioners and easing the demographic burden on pay-as-you-go social security systems. While many reforms have already been implemented,

[1] Numbers are from the OECD Social Expenditure Database (SOCX). As a comparison spending on unemployment insurance is 0.7 percent of GDP (1.5 percent of total government expenditure) across OECD countries in 2015.

[2] Examples for the empirical program evaluation literature in the retirement context are Mastrobuoni (2009); Behaghel and Blau (2012); Staubli and Zweimüller (2013); Manoli and Weber (2016a); Cribb et al. (2016) and in the disability insurance context Autor and Duggan (2003); de Jong, Lindeboom, and van der Klaauw (2011); Staubli (2011); Maestas, Mullen, and Strand (2013); Moore (2015); Gelber, Moore, and Strand (2017).

future reforms are inevitable to avoid the financial collapse of pay-as-you-go pension systems. The key question is: How should we reform pension systems? To answer this question Chapter 2 provides a novel, unifying framework to evaluate the welfare effects of pension reforms.

I show that the welfare effects of any reform rest crucially on the "fiscal multiplier"–the total fiscal effect relative to the mechanical fiscal effect. When reforming the pension rules, for example reducing pension levels, there are two effects on fiscal costs. First, lower pension levels mechanically reduce program costs (the mechanical fiscal effect). Second, individuals might respond to the new rules by delaying retirement, working longer and as a consequence paying more social security contributions. These changes in behavior create additional fiscal revenue (the behavioral fiscal effect). The total fiscal effect is the sum of the mechanical and behavioral fiscal effect. The total effect divided by the mechanical effect is what I refer to as the fiscal multiplier of a reform. The fiscal multiplier therefore measures by how much public funds increase for a one dollar reduction in pensions. We can think of any pension reform as a transfer of one dollar from the hands of a retiree to public funds. On the benefit side, public funds increase by the fiscal multiplier. On the cost side, retirees loose one dollar. I refer to this loss as the social value of the dollar. The social value of the dollar is the money metric of how valuable that one dollar is in the hands of the affected retirees. Hence, to assess the welfare effects of a pension reform we need to compare the benefits against the costs: A pension reform is welfare-improving if the multiplier is larger than the social value of the dollar.

Fiscal multipliers can be estimated with reduced-form methods using data on contributions to and transfers from the entire welfare state system. However, previous literature has not estimated fiscal multipliers of pension reforms. In the empirical part of Chapter 2, I exploit a series of pension reforms in Austria and estimate fiscal multipliers of increasing the early retirement age and reducing pension levels. I find that increasing the early retirement age has a fiscal multiplier of 1. This is surprising. Since individuals can no longer retire early, we expect them to work longer and pay more taxes, leading to additional fiscal revenue and hence a multiplier larger than 1. In response to the reform workers spend more time in employment, which generates additional social security contributions, but some individuals also spend more time in unemployment, which generates additional expenditures on unemployment insurance benefits. These two effects cancel, leading to a net-zero fiscal effect of behavioral responses. This finding implies that increasing the Austrian early retirement age is not welfare-enhancing–unless one thinks that \$1 in the hands of an early retiree has a lower social value than \$1 in public funds.

By contrast, reducing pension levels generates a multiplier of 1.5. This policy induces some workers to delay their retirement and stay longer in employment without triggering substitution to other welfare benefits. As a result, reducing pension levels is welfare improving, provided that taking \$1 away from a retiree is associated with a social loss smaller than \$1.5. In a standard calibration of the model, the social loss is smaller than \$1.5 for reasonable values of risk aversion suggesting that reducing pension levels was welfare-improving. The theoretical framework also allows to rank the welfare effects of the two reforms which answers whether we should rather increase the early retirement age or reduce pension levels. Based on my estimates, a social planner with preferences for redistribution clearly favors reducing pension levels over increasing the early retirement age. Reducing pension levels has a higher multiplier (1.5 vs. 1 of increasing the early retirement age) and plausibly has a lower social value of the dollar.[3] Hence, the ranking is clear as the pension level reform has higher social benefits (fiscal multiplier) and lower social costs (social value of the dollar).

Chapters 3 and 4 study disability insurance programs. In many countries the share of individuals receiving Disability Insurance (DI) has increased significantly over the past 50 years. For example, in the United States less than 1 percent of individuals in the age group of 20 to 64 were receiving DI benefits in 1960, but by 2012 this fraction had risen to 5.3 percent. Some European countries, like Norway and the United Kingdom, have experienced even stronger growth.

[3]The pension level reform mostly affected high-income individuals, while increasing the early retirement age affected everyone across the income distribution. If the costs of reducing transfers to high income individuals are lower than the costs of reducing transfers to everyone across the income distribution, then the pension level reform has lower social costs (social value of the dollar).

The rapid expansion of the DI beneficiary population has generated substantial interest by policy makers and economists in measures that reduce growth in program caseloads and expenditures. Autor and Duggan (2006) discuss three ways to limit the expansion of DI programs: (i) reduce incentives to seek DI benefits, (ii) adopt more rigorous eligibility standards and (iii) provide incentives to return to work. Chapter 3 studies the welfare effects of instruments (i) and (ii). Chapter 4 provides a framework to analyze policy (iii).

Chapter 3 is joint work with Stefan Staubli and Josef Zweimüller and titled "*Designing Disability Insurance Reforms: Tightening Eligibility Rules or Reducing Benefits?*". This Chapter provides a theoretical framework to evaluate the welfare effects of stricter DI eligibility rules versus lower DI benefits. We derive sufficient statistics formulas to quantify the trade-offs of these policy instruments and also show how these two instruments can be optimally combined. As in Chapter 2, the fiscal multiplier is of central importance. Estimating the fiscal multiplier of stricter DI eligibility rules, however, is not straightforward. Stricter eligibility rules lead mechanically to lower DI award rates but at the same time change application behavior. To directly estimate the mechanical effect of stricter eligibility rules one would need to know the hypothetical change in the award rates of individuals. This is a counterfactual we cannot observe.[4] Therefore, one of the empirical contributions of this Chapter is to develop an approach to construct this counterfactual.

The empirical analysis exploits exogenous variation in DI eligibility rules and benefit levels arising from several reforms in Austria. We find that stricter DI eligibility rules significantly reduces DI inflow through both a mechanical effect, capturing that fewer applicants qualify for benefits under the stricter rules, and a behavioral effect, capturing that less people apply for benefits. Moreover, a decrease in DI benefits is also associated with a significant reduction in DI inflow. We estimate fiscal multipliers of around 2-2.5 for stricter eligibility rules and around 1.4 for lower DI benefits.

Interestingly, the fiscal multiplier of reducing DI benefits is similar in magnitude to the fiscal multiplier of reducing old-age pension levels. The fiscal multiplier of stricter DI eligibility criteria is substantially higher than the multipliers I find for pension reforms. However, the population at risk is also very different across these programs implying differences in the social value of the dollar and making a comparison of reforms across programs difficult.[5]

Chapter 4 studies optimal work incentives in DI programs. It is joint work with Giacomin Favre and Stefan Staubli and is titled *"Offsetting the Cliff? A Sufficient Statistics Approach to Measuring the Welfare Effects of Work Incentives in Disability Insurance*". Most DI programs feature strong work disincentives, so called "cash cliffs". If DI beneficiaries have labor earnings beyond a certain income threshold, they loose their entire cash benefits. Instead, a benefit offset program reduces DI cash benefits gradually for individuals with an income above the threshold. Hence, there is an active policy discussion to replace these cash cliffs with a benefit offset. The hope is to reduce program costs by abolishing the strong work disincentives of a cash cliff.

Replacing a cash cliff with a benefit offset scheme has two opposing effects. On the one hand, the most able DI beneficiaries are incentivized to increase their labor supply (labor supply effect). This reduces program costs without reducing the insurance value of DI. On the other hand, DI becomes more attractive for potential applicants, which might cause more DI take-up (induced entry effect) and increased program costs. Our theoretical analysis formalizes this trade-off and shows that the welfare effects crucially depend on two sufficient statistics: (i) the earnings elasticity of DI recipients and (ii) the DI benefit take-up elasticity. The earnings elasticity captures the labor supply effect, and the DI benefit take-up elasticity is a sufficient statistic for induced entry in a broad class of models. Moreover, our theoretical analysis shows that the introduction of a benefit offset is unlikely to reduce program costs. A cost reduction requires at least an earnings elasticity above one, i.e. a disproportionately strong labor supply response of DI recipients to financial incentives. Nevertheless introducing a benefit offset can be welfare-improving because it increases

[4] Estimating the mechanical fiscal effect of a benefit level reform is straightforward as we can directly calculate by how much individual benefits change due to the reform. It is (usually) not possible to directly calculate the effect of a change in DI eligibility rules on DI award rates at the individual level.

[5] Potentially, a transfer to affected DI applicants might be socially more valuable than a transfer to the average retiree. This would imply a higher social value of the dollar for DI reforms compared to old-age pension reforms.

the insurance value. As an illustration, we implement our sufficient statistics formula for the U.S. based on estimates from previous studies. For the lowest estimates of the benefit take-up elasticity in the literature the introduction of a benefit offset is welfare-improving while for the highest estimates the introduction is welfare-reducing. In ongoing empirical work we exploit two policy reforms in Canada to estimate the labor supply and DI benefit take-up elasticity. This will provide more evidence on the effectiveness of benefit offset programs.

Chapter 2

Welfare Effects of Pension Reforms

Abstract. In almost all developed countries, policy makers have implemented pension reforms by increasing statutory retirement ages, lowering pension levels and/or adjusting pension formulas to address demographic change. This paper provides a novel, unifying framework to evaluate the welfare effects of such pension reforms. I show that the welfare effects of any reform rest crucially on the "behavioral fiscal multiplier"–the total fiscal effect relative to the mechanical fiscal effect (the mechanical effect is the fiscal effect absent any behavioral responses). Behavioral fiscal multipliers can be readily estimated with reduced-form methods using data on contributions to and transfers from the entire welfare state system. To illustrate my framework, I exploit a series of pension reforms in Austria. I find that increasing the early retirement age has a behavioral multiplier of 1. This means that the total fiscal effect is purely mechanical and there is no fiscal effect from behavioral adjustments. In response to the reform workers spend more time in employment, which generates additional social security contributions. However, individuals also spend more time in unemployment, which generates additional expenditures on unemployment insurance benefits. These two effects cancel, leading to a net-zero fiscal effect of behavioral responses. This finding implies that increasing the Austrian early retirement age is not welfare-enhancing–unless one thinks that \$1 in the hands of an early retiree has a lower social value than \$1 in public funds. By contrast, reducing pension levels generates a multiplier of 1.5. This policy induces some workers to stay longer in employment without triggering substitution to other welfare benefits. As a result, reducing pension levels is welfare improving, provided that taking \$1 away from a retiree is associated with a social loss smaller than \$1.5. In a standard calibration of the model, the social loss is smaller than \$1.5 for reasonable values of risk aversion suggesting that reducing pension levels was welfare-improving. My framework can also rank the welfare effects of the two reforms. Based on my estimates, a social planner with preferences for redistribution clearly favors reducing pension levels over increasing the early retirement age.

2.1 Introduction

Due to dramatically aging populations throughout the world, pension reforms are on the political agenda everywhere. The basic idea of pension reforms is to incentivize workers to delay their retirement, thus increasing the ratio of workers to pensioners and easing the demographic burden on pay-as-you-go social security systems.[1] Many countries have implemented pension reforms in the recent past. For instance, the U.S. has started to gradually increase the full retirement age from 65 to 67 and almost all European countries have implemented increases in the statutory retirement ages. Many countries have increased work incentives by reducing pension levels and/or by increasing the actuarial fairness of pensions. The hope is that these measures induce workers to postpone their retirement. While many reforms have already been implemented, future reforms are inevitable to avoid the financial collapse of pay-as-you-go pension systems. The key question is: How should we reform pension systems?

To answer this question we need to understand the welfare effects of pension reforms. While there exists a rich literature that evaluates the labor supply and fiscal effects of pension reforms (e.g. Mastrobuoni 2009; Behaghel and Blau 2012; Staubli and Zweimüller 2013; Manoli and Weber 2016a; Cribb et al. 2016), the link between the empirical estimates from the program evaluation literature to welfare consequences is missing so far. This paper aims to provide this link. I show that the welfare effect of a pension reform crucially depends on the "behavioral fiscal multiplier" and that behavioral fiscal multipliers can be credibly estimated with reduced-form methods. The behavioral multiplier of a reform is defined as the total fiscal effect divided by the mechanical fiscal effect. The mechanical fiscal effect measures the hypothetical effect of a reform on fiscal revenue if individual behavior did not respond to the reform. The mechanical fiscal effect can be directly calculated holding pre-reform behavior fixed. The total fiscal effect of a pension reform can be estimated with program evaluation methods. The existing literature estimates the total fiscal effects of pension reforms but usually does not identify the mechanical fiscal effect. However, this extra step of relating the total effect to the mechanical effect (i.e. the behavioral multiplier) is crucial for welfare evaluation.

Why is the behavioral multiplier key for welfare evaluation? One can think of a pension reform as taking away one dollar from a retiree and transferring it to public funds. Different pension reforms simply target different groups of retirees. For example, an increase in the early retirement age takes away one dollar from early retirees, a cut in pension levels takes away one dollar from all retirees. A reform then mechanically increases public funds by one dollar. Additionally, a reform induces behavioral responses. Individuals adjust to the new rules, e.g. by delaying retirement and working longer, which further increases public funds. In total, taking away one dollar from a retiree increases public funds by the behavioral multiplier. However, taking away one dollar from a retiree comes at a social cost. This social cost depends on the relative social valuation of one dollar in the hands of a retiree versus one dollar in public funds. I refer to this cost as "the social value of the dollar." If one dollar is socially more valuable in the hands of a retiree, the social value of the dollar is above one. If one dollar is socially more valuable in public funds, the social value of the dollar is below one. The social value of the dollar, therefore, measures the social cost of transferring one dollar from retirees to public funds in dollar terms. More specifically, the social value of the dollar depends on three things. First, it depends on how valuable this dollar is to the affected retirees (measured by their marginal utility of consumption). Second, it depends on the welfare weights the social planner attaches to the group of affected retirees. Third, it depends on the social value of public funds, i.e. the social value of whatever else the planner would use this dollar for, or put differently, the social cost of raising public funds.[2]

In summary, taking away one dollar from retirees (a pension reform) has a social benefit of increasing public funds by the behavioral multiplier, but comes at the cost of the social value of the dollar. Hence, to evaluate the welfare effect of a reform, we need to compare the behavioral

[1] In pay-as-you-go pension systems, working-age individuals pay for the pensions of the currently old generation.

[2] Importantly, economic theory tells us that behavioral adjustments to small reforms do not have direct welfare effects (by the envelope theorem) and hence do not enter in the social value of the dollar.

multiplier to the social value of the dollar (social benefits vs. social costs). If the behavioral multiplier is larger than the social value of the dollar, the reform is welfare improving (social benefits exceed social costs) and vice versa. The social value of the dollar does not directly relate to moments in the data.[3] After all, the social value of the dollar depends on the value that society as whole puts on a marginal increase of public funds relative to a decrease in pension generosity. This is a judgment call but under reasonable assumptions on the efficiency of the tax system and social preferences the social value of the dollar is larger than one, i.e. one dollar in the hands of a retiree has at least a social value of one dollar. In contrast, the behavioral multiplier can be readily estimated from data on fiscal costs and revenues that are generated by individuals' behavioral responses to the reform. The behavioral multiplier is essential, because it is the benchmark against which to judge the social value of the dollar. Under certain circumstances, knowing only the behavioral multiplier (but not the social value of the dollar) suffices to assess whether a pension reform was welfare improving or not. In my empirical analysis, the size of the estimated multipliers (and the characteristics of the affected workers) imply that only mild assumptions on social preferences are needed to make clear-cut statements about the welfare effects of these reforms.

In the empirical analysis of the paper, I estimate the behavioral multiplier of increasing the early retirement age and the behavioral multiplier of reducing pension levels by exploiting a series of pension reforms in Austria. Austria provides an ideal set up for three main reasons. First, seven pension reforms changed the early retirement age, pension levels and actuarial fairness of the pension formula at least once. Austrian policy makers phased in most policy changes yielding vast quasi-experimental variation. Second, the Austrian pension formula is very similar to other developed countries' pay-as-you-go formulas and the Austrian pension reforms changed margins that relate to current policy discussions. Third, the Austrian Social Security Data (ASSD) is an ideal data source to estimate behavioral multipliers of pension reforms. The ASSD does not only include information on the complete labor market and earnings history of workers since 1972 but also the history of take-up of welfare state programs (such as unemployment insurance, disability insurance and sickness benefits). As I will demonstrate below, changes in take-up of social insurance programs crucially affect the size of the behavioral multiplier.

To estimate the behavioral multiplier of increasing the early retirement age (ERA), I exploit two pension reforms in 2000 and 2003 that increased the ERA in steps from 55 to 60 for women and from 60 to 65 for men. The increase in the ERA is phased in by quarters of birth. With a difference-in-difference strategy, I find large and positive fiscal revenue effects of increasing the ERA. However, this fiscal revenue effect is purely mechanical, implying that the behavioral multiplier of this reform is one and in some cases as low as 0.9. This is surprising. Since individuals can no longer retire early, we expect them to work longer and pay more taxes, leading to additional fiscal revenue and hence a large behavioral multiplier. While there is a positive fiscal effect through additional payroll tax revenue, there are also additional expenditures from individuals substituting to unemployment benefits. It turns out that these two effects cancel out each other. The net fiscal effect from behavioral adjustments is therefore zero, leading to a behavioral multiplier of one. Interestingly, this finding implies that increasing the Austrian early retirement age is not welfare-enhancing – unless one thinks that \$1 in the hands of an early retiree has a lower social value than \$1 in public funds. As I show in the theoretical part of the paper, a natural lower bound for the social value of the dollar is one. Hence, the ERA reform with a behavioral multiplier of one is unlikely to be welfare-enhancing.

To estimate the behavioral multiplier of reducing pension levels, I exploit a 1988 reform using a regression discontinuity design. The reform changed the pension formula by date of birth in a particular way that made pensions by about 1.25% less generous on average.[4] For this reform, I find

[3] I am not aware of other papers that have related the social value of a dollar to empirical estimates in the retirement context. In the unemployment insurance literature, there are exciting new approaches on this frontier (e.g. Hendren (2017) and Landais and Spinnewijn (2019)). These approaches might also be applied in the retirement context but require data on consumption and saving decisions of individuals.

[4] An individual's pension is determined by her assessment basis multiplied with her pension coefficient. The assessment basis measures the average earnings over a specific period (assessment period) after applying a cap to

large behavioral multipliers of around 1.5. In response to the reform, I find that individuals delay their retirement and work longer. This increases fiscal revenue both by a reduction in spending on pensions and by additional pay-roll tax revenue. There is no substitution to other welfare benefits that would counteract this effect. In sum, this produces a behavioral multiplier of 1.5. Hence, reducing pension levels is welfare improving – provided that taking one dollar away from a retiree is associated with a social loss smaller than 1.5 dollars. In a standard parametrization of the model with CRRA utility I find that the social loss is smaller than 1.5 dollars for reasonable values of risk aversion. Hence, reducing pension levels is welfare-enhancing. The result that reducing pension levels generates behavioral multipliers substantially larger than 1 is surprising. A reduction in pension levels has a large mechanical effect, since individual's pensions are lower for the rest of their life. Moreover, a change in pension levels might be less salient and more complicated to understand than increasing the ERA. Therefore, one might not expect that individuals change their labor supply and retirement decision in response to this reform.

My framework also allows comparing the welfare effect of increasing the ERA to the welfare effect of reducing pension levels. Based on my estimates, a social planner with preferences for redistribution clearly favors reducing pension levels over increasing the ERA. Reducing pension levels has a substantially higher behavioral multiplier of 1.5 compared to the ERA reform with a behavioral multiplier of 1. Moreover, the pension level reform did not uniformly cut pension levels but disproportionately affected high income earners, while the ERA reform affected individuals across the income distribution. This implies a lower social value of the dollar for the pension level reform, since taking away one dollar from high income retirees is less costly than taking away one dollar from all retirees. Hence, reducing pension levels has a higher social benefit (behavioral multiplier) and comes at lower social costs (social value of the dollar) compared to increasing the ERA. Therefore, reducing pension levels is preferable to increasing the ERA in the Austrian context.

The more general message of my analysis is that spillovers to other welfare systems are of first-order importance and labor market opportunities of older workers are key in this respect. The behavioral multiplier summarizes these effects. If my framework is applied to reforms in other countries, the welfare implications can be very different depending on the labor market responses of affected workers.

Contribution to Literature. The logic that the behavioral multiplier is central to welfare evaluation is not new. This is a direct consequence of the envelope theorem and the foundation of the sufficient statistics literature. The previous literature on sufficient statistics has mainly focused on optimal unemployment insurance and taxation. There is a lot of recent and exciting work done in these areas (for an overview of this literature see Chetty and Finkelstein (2013); Kleven (2018a) and for recent papers on unemployment insurance see Chetty (2006a); Shimer and Werning (2007); Chetty (2008); Schmieder et al. (2012); Kolsrud et al. (2018)). This is the first paper to take this idea to the retirement context and show that reduced-form estimates are informative for welfare effects of pension reforms. In the retirement context, with complicated dynamics and multiple generations, it is not obvious what the relevant reduced-form estimates are and whether we can estimate them. This paper demonstrates that the behavioral multiplier of a reform is central and that it can be credibly estimated with reduced-form methods. There are two recent working papers that closely connect to my paper. Lee et al. (2019) estimate the fiscal externality (behavioral multiplier minus 1) for two unemployment policies. Hendren and Sprung-Keyser (2019) estimate the marginal value of public funds (willingness to pay for a policy divided by the behavioral multiplier) for 133 historical policy changes in the United States, focusing on policies in social insurance, education and job training, taxes and cash transfers, and in-kind transfers. Both papers argue, as I do as well, that these measures a key for welfare analysis of policy changes.

The empirical part of this paper contributes to the large and growing reduced-form literature evaluating past pension reforms (Duggan et al., 2007; Mastrobuoni, 2009; Behaghel and Blau,

earnings in each year. The 1988 pension reform increases the assessment period from the last 10 years to the last 11 years for men born after January 1st 1928 and for women born after January 1st 1933. Due to seniority wages this decreases pension by 1.25% on average.

2012; Staubli and Zweimüller, 2013; Manoli and Weber, 2016a; Cribb et al., 2016; Seibold, 2019) by evaluating the labor supply and fiscal implications of increasing the ERA and reducing pension levels. Staubli and Zweimüller (2013) and Manoli and Weber (2016b) study the same ERA reform as this paper. My analysis uses a slightly different identification strategy and estimates the behavioral multiplier of the reform as a new outcome. The theoretical framework provides a new perspective on the welfare effects of this reform. The pension level reform has not been studied before.

There is also a large literature on structural retirement models (Gustman and Steinmeier, 1986; Stock and Wise, 1990; Berkovec and Stern, 1991; Rust and Phelan, 1997; French, 2005; van der Klaauw and Wolpin, 2008; Iskhakov, 2010; Laitner and Silverman, 2012; Imrohoroglu and Kitao, 2012; Gustman and Steinmeier, 2015). This literature performs counterfactual analysis of social security reforms in estimated models to understand the labor supply and welfare effects of pension reforms. I view this structural approach as complementary to my paper. For instance, in my empirical analysis I cannot observe the labor supply response to a reform over the entire life-cycle of an individual (especially at younger ages). In policy simulations, French (2005) finds very little life-cycle variation in hours worked between ages 30 and 55, suggesting that my empirical analysis might not be missing a substantial effect by ignoring outcomes at younger ages. In the other direction, careful reduced-form empirical analysis of pension reforms can be informative for structural model building.

Road-map. Section 2.2 develops the theoretical framework for welfare evaluation. Section 2.3 describes the institutional background in Austria, the seven pension reforms and the data. The empirical analysis in section 2.4 is divided in two parts. Section 2.4.1 estimates the behavioral multiplier of increasing the early retirement age. Section 2.4.2 estimates the behavioral multiplier of decreasing pension levels. Finally, Section 2.5 concludes. Various model extensions and robustness checks are relegated to the Appendix.

2.2 Model

This section develops the framework to evaluate welfare effects of pension reforms. The model is in the spirit of the sufficient-statistics literature. I show that in a large class of models the multiplier of a pension reform, which can be estimated with reduced-form methods, is key for welfare evaluation.[5] Pension reforms are challenging to evaluate because there are effects within and between generations. I start with a life-cycle model of only one generation to illustrate the key trade-offs. In Appendix 2.A.4 I show that with multiple overlapping generations we want to estimate the exact same multiplier as with only one generation. The logic of the argument is that we want to design the optimal pension formula for each generation and hence need to know the multiplier of a reform within one generation.

Agents. There is a continuum of agents indexed by $i \in I$ facing a life-cycle of T periods. Agent's expected life-time utility, denoted by $U_i(C, \Pi, X)$, depends on their consumption C, other choices Π (such as labor supply), and the full state history X. In each period, an agent is in a specific state x_t with a state history $x^t = \{x_i\}_{i=0}^{t-1}$. A state is described by assets a_t and a vector of other states s_t, i.e. $x_t = \{a_t, s_t\}$. The other states s_t can include, but are not limited to, labor market status, past earnings, health, productivity and mortality. This formulation is flexible, allowing, for instance, for utility depending on labor markets status, health status, productivity or age. In particular, this can also capture differences in longevity. While I fix the maximum length of life to T periods, this is not restrictive. Differences in longevity can be modeled as a state variable "death" that sets the utility function to zero for all future periods and T can be arbitrarily large. Each period, an agent chooses consumption $c_t(x^t)$ and other choices $\pi_t(x^t)$, which includes labor income $y_t(x^t)$ and a vector $p_t(x^t)$ of other behaviors. $C \equiv \big(c_0(x^0), c_1(x^1), \ldots, c_{T-1}(x^{T-1})\big)$ and $\Pi \equiv \big(\pi_0(x^0), \pi_1(x^1), \ldots, \pi_{T-1}(x^{T-1})\big)$ denote the contingent life-cycle plan of an agent. The agent therefore solves the following optimization problem

[5] In what follows, I will use "multiplier" when I refer to the "behavioral multiplier."

$$V_i = \max_{C,\Pi} U_i(C, \Pi, X) \tag{2.1}$$

subject to the constraints

$$a_{t+1} = (1 + r_t)a_t + y_t(x^t) - \tau(x^t) + b(x^t) - c_t(x^t) - q(p_t(x^t)) \tag{2.2}$$

and

$$s_{t+1} = f\left[s^t, \pi_t(x^t), \varepsilon_t\right]. \tag{2.3}$$

The constraints impose minimal structure on the evolution of state variables. For assets, I impose the standard budget constraint (2.2) stating that for every state history x^t in each period t assets tomorrow a_{t+1} equal assets today a_t plus capital income $r_t a_t$, plus after tax income $y_t(x^t) - \tau(x^t)$ and benefit receipt $b(x^t)$, minus consumption $c_t(x^t)$ and expenditures of the other choices $q(p(x^t))$.[6] Constraint (2.3) characterizes the evolution of the other state variables such as labor market status or health, and is assumed to follow some process $f\left[s^t, \pi_t(x^t), \varepsilon_t\right]$. This process is allowed to depend on the full state history s^t, the random component ε_t and choices π_t.

Social Planner. The social planner can specify state-history-dependent transfers $b(x^t)$ and taxes $\tau(x^t)$. These functions capture all kinds of (un-)conditional transfers and taxes and therefore, in principle, describe the entire welfare state. When choosing the benefit and tax function, the social planner faces a revenue constraint $G(b, \tau) \geq \bar{G}$, where revenue is defined as the present value of taxes minus transfers. The planner's objective function sums over the indirect utilities V_i of all agents weighted by welfare weights ω_i. The planner therefore solves

$$\max_{b(\cdot),\tau(\cdot)} W(b, \tau) = \int \omega_i V_i di \tag{2.4}$$

subject to

$$G(b, \tau) = \sum_{t=0}^{T-1} \left[1 + r_t\right]^{-t} E\left[\tau(x^t) - b(x^t)\right] \geq \bar{G}. \tag{2.5}$$

The expectation operator in (2.5) is defined over the distribution of state histories, which depends on the agent's choices C and Π.[7]

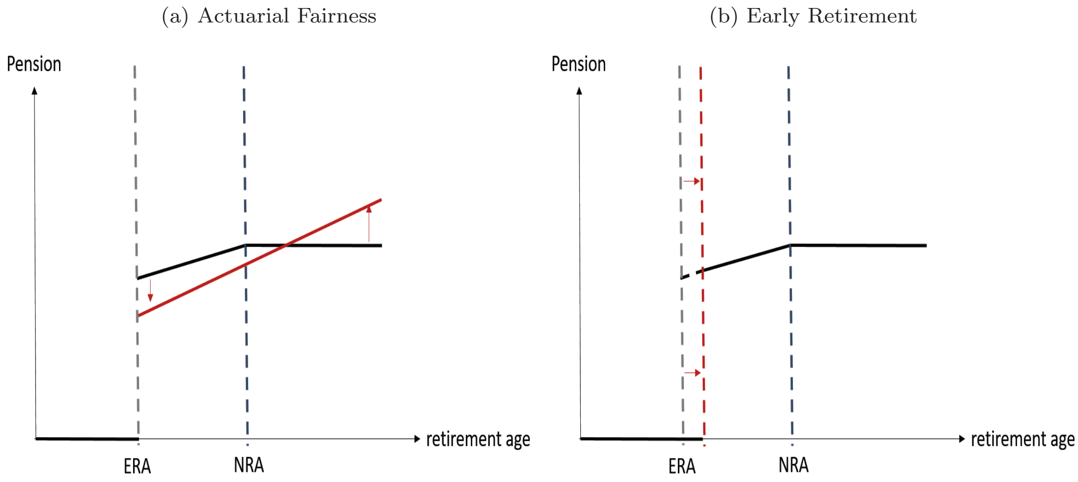
Fréchet Derivative. The social planner is optimizing over functions. To formalize this I use the Fréchet derivative, which is a generalization of the concept of directional derivatives to functions.[8] The Fréchet derivative $\delta W(b; h)$ measures the change in social welfare $W(b, \tau)$ if the benefit function $b(\cdot)$ is tilted in direction of the function $h(\cdot)$. Intuitively, one can think of changing the current benefit function $b(\cdot)$ in direction $h(\cdot)$ as a specific reform that changes the pension formula in particular way. Different directions $h(\cdot)$ can capture changes in pension generosity (level shift in benefit function), in actuarial fairness (slope of the benefit function) and early and normal retirement age (shift to the right in the age dimension). Figure 2.1 illustrates this idea graphically. In summary, the Fréchet derivative is a powerful tool to capture arbitrarily complicated (marginal) changes in the benefit function and therefore any small pension reform can be evaluated in my framework.

[6] $q(\cdot)$ is mapping the other choices $p_t(x^t)$ into monetary expenditures.

[7] Formally, $\sum_{t=0}^{T-1} \left[1 + r\right]^{-t} E\left[\tau(x^t) - b(x^t)\right] = \int \sum_{t=0}^{T-1} \left[1 + r\right]^{-t} \left[\tau(x^t) - b(x^t)\right] \mu(d(\varepsilon_0, \ldots, \varepsilon_{T-1})|x_0, C, \Pi)$ where $\mu(d(\varepsilon_0, \ldots, \varepsilon_{T-1})|x_0, C, \Pi)$ is the product measure on the cross product of Υ^T (the space of the error terms ε_t) and T copies of Υ, since $x_t = \{a_t, s_t\}$ can be expressed in terms of $(\varepsilon_0, \ldots, \varepsilon_{T-1})$ via (2.2) and (2.3). For notational ease, I assume that the distribution of state histories has a density function, denoted by $\mu(x^t; C, \Pi)$. This is not crucial for the argument but allows me to write the expectation operator as $\sum_{t=0}^{T-1} \int \left[1 + r\right]^{-t} \left[\tau(x^t) - b(x^t)\right] \mu(x^t; C, \Pi) dx^t$.

[8] See Luenberger (1997) for a formal treatment.

Figure 2.1: Illustration Fréchet Derivative



Notes: This figure illustrates the idea of the Fréchet derivative. Suppose the black line is the pre-reform benefit function and the red line the post-reform benefit function. In panel (a) we change the slope of the benefit function. Individuals who retire early face a reduction in their benefits. Hence, the direction of change $h(\cdot)$ is negative for these individuals. Individuals who retire later face an increase in their benefits and their direction of change $h(\cdot)$ is positive. Panel (b) illustrates an increase of the early retirement age (ERA). This shifts the whole benefit function to the right.

Optimal Benefit Function. Suppose the planner implements a particular pension reform, i.e. the benefit function is changed in the direction of a measurable function $h : X \to \mathbb{R}$. The welfare effect of this reform is given by

$$\delta W(b; h) = \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C, \Pi, X)}{\partial c_t(x^t)} h(x^t) \right] di + \lambda * \delta G(b; h). \tag{2.6}$$

The first term measures the direct welfare effect of changing the benefit function. This direct welfare effect is given by the change of the benefit function $h(x^t)$ multiplied by the marginal utility of consumption $\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)}$ of agent i in that state multiplied by her welfare weight ω_i. This direct effect only depends on the mechanical effect of the reform. The Envelope theorem ensures that behavioral adjustments do not have a first-order welfare effect. The second term, $\lambda * \delta G(b; h)$, captures the social value of the fiscal effect of the reform. $\delta G(b; h)$ is the total change in fiscal revenue and consists of two separate effects: The mechanical and behavioral fiscal effect. The mechanical fiscal effect, $M(h)$, is the hypothetical change in fiscal revenue if agents' behavior did not respond to the reform. Formally, this simply sums up all changes in the benefit function $h(\cdot)$ at the pre-reform behavior, i.e. at the pre-reform state-history distribution

$$M(h) = \int \sum_{t=0}^{T-1} \left[1 + r_t\right]^{-t} E_i \left[-h(x^t)\right] di. \tag{2.7}$$

The behavioral effect $B(h)$ measures the hypothetical change in fiscal revenue of the reform if only agents' behavior adjusted and the benefit function was held constant. Formally, the behavioral effect is given by

$$B(h) = \int \sum_{t=0}^{T-1} \int \left[1 + r\right]^{-t} \left[\tau(x^t) - b(x^t)\right] \delta\mu(x^t; h) dx^t di, \tag{2.8}$$

where $\delta\mu(x^t;h)$ measures the change in the state-history distribution due to changes in the agents' behavior. The sum of these two effects yields the total fiscal revenue effect $\delta G(b;h) = M(h)+B(h)$. Lastly, the multiplier on the planner's budget constraint, λ, converts the fiscal revenue effect from dollars to welfare. λ measures the social value of a dollar in public funds. This value depends on what the planner uses the dollar for. As I formally show below, a natural lower bound for λ is the average marginal utility of consumption in the population. In this case, the planner would simply redistribute the dollar lump-sum across all individuals.

The optimal benefit function then ensures that there is no potential welfare improvement from any reform, i.e. that $\delta W(b;h) = 0$ for all deviations $h(\cdot)$. Starting from (2.6) the optimal benefit function therefore fulfills

$$\underbrace{\frac{\frac{1}{M(h)}\int \omega_i E_i\left[\sum_{t=0}^{T-1}\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)}h(x^t)\right]di}{\lambda}}_{\text{Social value of the dollar}} = \underbrace{1+\frac{B(h)}{M(h)}}_{\text{Multiplier}} \tag{2.9}$$

for all deviations $h(\cdot)$. A formal proof of this optimality condition can be found in Appendix 2.A. Normalizing the welfare effect by the mechanical effect $M(h)$ provides the same metric for all reforms in equation (2.9), making an increase in the early retirement age comparable to a cut in pension levels. The thought experiment in equation (2.9) is therefore to take away one dollar from retirees through a specific reform. The LHS of (2.9) measures the social value of the dollar in the hands of the affected group. The RHS of (2.9) measures the multiplier of the reform, i.e. how much additional fiscal revenue is generated by behavioral responses of agents on top of the mechanically saved dollar. Formula (2.9) nests the Baily-Chetty formula for optimal unemployment insurance benefits as a special case as I illustrate in Appendix 2.A.3.

Welfare Effect of a Reform. How is equation (2.9) useful for thinking about welfare effects of actual pension reforms? Suppose we have a specific reform that makes the pension system less generous, for instance a reduction in pension levels. Further suppose that we can determine the social value of the dollar (LHS of (2.9)) and the multiplier (RHS of (2.9)) of this reform. If we find that the multiplier is larger than the social value of the dollar, we can conclude that the reform is welfare improving.

$$\delta W(b;h) \gtreqless 0 \;\Leftrightarrow\; \underbrace{\frac{\frac{1}{M(h)}\int \omega_i E_i\left[\sum_{t=0}^{T-1}\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)}h(x^t)\right]di}{\lambda}}_{\text{Social value of the dollar}} \lesseqgtr \underbrace{1+\frac{B(h)}{M(h)}}_{\text{Multiplier}}$$

If we find that the social value of the dollar is larger than the multiplier of the reform, we would have better not changed the system and the dollar is better left in the hands of the retirees. In that case the reform is welfare-reducing. If the pension system was optimal before the reform, the social value of the dollar and the multiplier would be equal.

But can we get credible estimates of the social value of the dollar and the multiplier of a reform? In principle we can estimate the multiplier of a reform with reduced-form methods. The social value of a dollar, however, is not directly related to observed moments in the data. In the end this is a judgment call of the planner, since it will always depend on the welfare weights a planner chooses. Nevertheless, knowing the multiplier of a reform is informative. The multiplier provides the benchmark of how high the social value of a dollar must be such that the reform is no longer welfare improving. For instance, assume reducing pension levels has a multiplier of 1.5, meaning that for each mechanical dollar there is an additional 50 cents reduction in expenditures due to behavioral response (e.g. individuals retire later and pay more taxes). Reducing pension levels is then welfare improving as long as the dollar in the hands of the affected retirees is valued at less than 1.5 dollars. To illustrate the magnitude of the social value of the dollar I also parameterize the model. Appendix 2.A.5 provides the details for this exercise.

Lower Bound for the Social Value of the Dollar. A natural lower bound for the social value of the dollar is unity, meaning that one dollar in the hands of a retiree has a social value of at least one dollar. To derive this lower bound, we need to make two assumptions. First, assume that welfare cannot be improved through higher lump-sum taxation. This is a fairly mild assumption on the efficiency of the tax system and implies that λ is smaller than the average marginal utility of consumption in the population. Second, assume a utilitarian planner, i.e. $\omega_i = 1 \, \forall i$.[9] With these two assumptions we can bound the social value of the dollar by the average marginal utility of consumption of individuals affected by the pension reform divided by the average marginal consumption in the population, i.e.

$$\text{Social Value of the Dollar} \geq \frac{\int E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t)\right] di}{\int E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} \overline{h}\right] di} \geq 1 \tag{2.10}$$

where $\overline{h}$ is the lump-sum transfer, which would redistribute the mechanical effect from the reform $M(h)$ equally across all agents and periods. If we think that the marginal utility of consumption of retirees affected by the reform is larger than the average marginal utility of consumption in the population, then the social value of the dollar is larger than unity. Put differently, the social value of the dollar is larger than unity if we think that a transfer to retirees is socially more valuable than a transfer to all individuals. The formal argument for this lower bound is in Appendix 2.A.2. In consequence, a reform with a multiplier below unity cannot be welfare-improving if we are willing to make these fairly mild assumptions.

Ranking Welfare Effects of two Reforms. Multipliers of reforms can be informative to rank the welfare effects of two reforms without exactly pinning down the social value of the dollar. For instance, if two reforms target the same individuals, the social value of the dollar is identical. Hence, the multipliers are sufficient to rank the two reforms and the reform with the higher multiplier is preferable. In practice, we do not have two reforms that target the exact same individuals. However, we might have two reforms where we can rank the social value of the dollar of the two reforms under mild assumptions on the planner's preferences. For instance, assume that we have two reforms A and B. Suppose that reform A reduces pension levels for high income individuals while reform B reduces pension levels for all individuals. In this case the social value of the dollar of reform A is lower than the social value of the dollar of reform B if we assume the planner has redistributive preferences (since it is less costly to take away one dollar from rich individuals). If reform A also has the higher multiplier we can conclude that reform A is preferable to reform B.

Formally, the difference of the welfare effects of the two reforms is the difference in the multipliers (first line in equation below) minus the difference in the social value of the dollar (second line). If the multiplier of reform A is larger than the multiplier of reform B, the first term is positive. If the planner has preferences for redistribution and reform A targets higher income individuals compared to reform B, then the social loss of reform B is larger and the term in the second line is positive. As a consequence, reform A is unambiguously preferable to reform B.

$$\begin{aligned} \delta W(b; h_A) - \delta W(b; h_B) &= \left(\left[1 + \frac{B(h_A)}{M(h_A)}\right] - \left[1 + \frac{B(h_B)}{M(h_B)}\right] \right) \\ &+ \frac{1}{\lambda} \left(\frac{\int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h_B(x^t)\right] di}{M(h_B)} - \frac{\int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h_A(x^t)\right] di}{M(h_A)} \right) \end{aligned}$$

Estimating the Multiplier. The ideal experiment to estimate the multiplier of a reform would be to observe a treatment and control group under the pre- and post-reform regime over their life-cycle. In this case the multiplier can be estimated in three steps:

[9] This simplifies the argument and rules out that a planner would put zero weights on individuals, who are affected by the reform.

1. Estimate Total Fiscal Effect $T(h)$ as the mean difference in life-cycle fiscal revenue between treatment and control group.
2. Calculate the Mechanical Fiscal Effect $M(h)$: Calculate life-cycle fiscal revenue in the control group under both the pre- and post-reform pension regime (holding behavior fixed). The difference in fiscal revenue is the mechanical effect.
3. Compute the Behavioral Fiscal Effect as residual $B(h) = T(h) - M(h)$.

Reduced-form methods, such as difference-in-difference or regression-discontinuity estimators, can deliver credible estimates on the total fiscal effect of a reform. The mechanical effect of a reform is straightforward to calculate. The challenge of estimating the multiplier, however, is the life-cycle aspect and the ideal experiment does not usually exist. Typically, individuals learn about changes in their pension rules around age 50 to 60 and not already at the beginning of their life. If they knew about the reform already at younger ages, forward-looking individuals might adjust their behavior in anticipation of the reform. Hence, the challenge is to estimate these potential anticipation effects of a pension reform. For some of the Austrian reforms, individuals learned about changes in their rules well in advance and I provide evidence that anticipation seems not to play a key role. In the empirical part of the paper, I therefore argue that we can get a good sense of the multiplier of a pension reform with reduced-form methods.

Extensions. In appendix 2.A.4 I show that with multiple overlapping generations we want to estimate the exact same multiplier as in the one generation setup to evaluate welfare effects of pension reforms. The logic of the argument is that we want to design the optimal pension formula for each generation and hence need to know the multiplier of a reform within each generation. The social value of the dollar now also accounts for the relative valuation of a dollar in the hands of the current generation versus in the hands of future generations. Appendix 2.A.6 discusses how the welfare evaluation changes in case of general equilibrium effects, non-marginal changes or behavioral biases of agents. In presence of these effects, there is an additional term on the LHS of formula (2.9), i.e. the direct welfare effect looks different. The RHS is still the multiplier of the reform. In particular, non-marginal changes and behavioral biases imply that behavioral adjustments have first-order welfare effects. In case of non-marginal reforms we can sign the additional term on the LHS. Behavioral adjustments to non-marginal reforms are costly and increase the social value of the dollar. Hence, if a reform is welfare-reducing in the marginal change framework, the reform is even more welfare-reducing if we account for the direct costs of behavioral adjustments. With behavioral biases the sign of the additional term (the "bias correction term") depends on whether a reform reduces or amplifies the bias. For example, suppose individuals are myopic and a reform induces them to retire later and save more. In this case, the reform reduces the bias (myopic individuals save too little and retire too early from the viewpoint of a paternalistic planner) and hence accounting for this bias term reduces the social value of the dollar making the reform more attractive.

2.3 Institutional Background and Data

2.3.1 The Public Pension System in Austria

The Austrian public pension system covers all private-sector workers. The system is primarily financed as a pay-as-you-go system, but financial shortfalls have to be covered by the federal budget.[10] The other pillars of the pension system are of minor importance.[11] Public pensions are

[10] In 2017, the share coming from the federal budget (the so-called "Bundesbeitrag") amounted to about 1.7% of GDP or 17.2% of overall spending for old-age pensions (HV, 2018).

[11] Funded company pension schemes, comparable to 401(k) plans in the U.S., are not mandatory and in 2007 less than 20% of the Austrian workforce was covered by such plans. Since 2002, there has been a new severance pay scheme where employers transfer 1.53% of the monthly salary to a pension account. The contribution rate to the pay-as-you-go pension system is 22.8%. Third-pillar pensions ("Prämienbegünstigte Zukunftsvorsorge") have only been available since 2003. For more details see Fink (2009).

the main source of income for retirees and they replace on average 75% of the pre-retirement net earnings. Public pensions are calculated as a function of insurance years, experience, retirement age and past wages. Since 1985 Austria had seven major pension reforms that changed the benefit formula substantially. In general, the pension benefit formula consists of two parts, the assessment basis and the pension coefficient:

$$\text{old-age pension} = \text{assessment basis} \times \text{pension coefficient}.$$

The assessment basis measures the average earnings over a specific period after applying a cap to earnings in each year. The assessment basis is comparable to the Average Indexed Monthly Earnings (AIME) in the U.S. system. The pension coefficient is the individual's replacement rate (in percent) that is applied to the assessment basis. The pension coefficient is a function of the number of insurance years and the claiming age.[12]

Individuals with more than fifteen insurance years are eligible to claim old-age pensions. The normal retirement age (NRA) is 60 for women and 65 for men. The early retirement age (ERA) was 55 for women and 60 for men and was step-wise increased to 60 for women and to 65 for men. Since 2005, individuals with more than 37.5 insurance years can still retire early at age 62. In Austria, pension eligibility and payments always depend on individual accounts. It is not possible to qualify for retirement benefits through one's spouse's contribution record.

2.3.2 Pension Reforms since 1985

Since 1985 Austria has had seven major pension reforms. The seven reforms changed all relevant margins of the pension benefit formula at least once and Austrian policy makers phased in most policy changes yielding vast quasi-experimental variation. The early reforms in 1985 and 1988 reduced pension levels by adjusting the definition of the assessment basis. The pension reforms in 1993, 1996, 2000 and 2003 changed the actuarial fairness by adjusting the pension coefficient to penalize early claiming. The reforms in 2000 and 2003 also increased the early retirement age. Table 2.1 provides an overview of the seven pension reforms. The changes in the assessment basis, pension coefficient and retirement ages were all phased-in with complicated transition rules. This creates quasi-experimental variation in pension rules, which I exploit in my empirical analysis. I explain the complicated transition rules and how I exploit them in section 2.4 in detail. In the following, I shortly describe how the three main determinants of the pension formula, the assessment basis, the pension coefficient and the retirement age, changed over time.

Assessment Basis. Before 1985, the assessment basis was calculated as the average earnings in the last five years. The pension reform in 1985 increased the assessment period from the last five to the last ten years. In 1988, this period was further increased from the last ten years to the last fifteen years. These reforms reduced the pension level for most individuals, since the average earnings of the last fifteen years are lower than the average earnings in the last five years for individuals with increasing wage profiles due to seniority effects. In 1993, the assessment basis was again changed from the average earnings of the last fifteen years to the average earnings of the best fifteen years. For most individuals, the best fifteen years are exactly the last fifteen years and this reform did not substantially change pension levels. Starting in 2004, the assessment period was step-wise increased from the best fifteen years to the best 40 years. This change was phased in between 2004 and 2028; each year the assessment period increased by one year.

Pension Coefficient. Before 1993, the pension coefficient only depended on the number of insurance years and was independent of the claiming age. Up to 30 insurance years, each insurance year increased the pension coefficient by 1.9 percentage points. Above 30 insurance years, the pension coefficient increased by 1.5 percentage points with each additional insurance year up to a maximum of 80%. The maximal pension coefficient was therefore reached at 45 insurance years.

[12]Insurance years include both contribution years (i.e., periods of employment, including sick leave) and non-contributory periods of labor force participation (e.g., unemployment).

The pension reform in 1993 introduced a bonus for claiming pensions after the early retirement age. This made pensions more generous for individuals who claim after the early retirement age. For each month after the early retirement age the pension coefficient was scaled up by a certain factor. For example, claiming five years after the early retirement age scaled the pension coefficient up by a factor of 1.11. The reform in 1996 introduced a penalty for claiming before age 56 for women and 61 for men. This penalty for claiming early depends on the number of insurance years. The pension reforms in 2000 and 2003 further changed the penalty. Since 2000, each insurance year increases the pension coefficient by two percentage points and the penalty for each year claiming before the NRA is set at three percentage points with a maximum penalty of ten percentage points. The reform in 2003 further increased this penalty to 4.2 percentage points per year with a maximum of 15%. These changes were phased in over time with complicated caps on benefit losses with respect to prior rules.

Retirement Age. The reforms in 2000 and 2003 also increased the early retirement age in steps for men from 60 to 65 and for women from 55 to 60. The normal retirement age will be increased from 60 to 65 for women in 2024. Interestingly, this change was already enacted in 1993. While the actual change has not taken place yet, the announcement almost 30 years ago allows studying anticipation effects over long periods of time and shedding light on forward-looking behavior of individuals with respect to increases in the normal retirement age.

2.3.3 Other Social Insurance Programs

Apart from old-age pensions, there are three other important social insurance programs in Austria: disability insurance (DI), sickness insurance (SI), and unemployment insurance (UI). The DI program provides partial earnings replacement to workers below the full retirement age who have accumulated at least 5 insurance years within the last 10 years and have a health impairment that is considered severe. DI benefits are calculated in a similar fashion as old-age pensions (based on the assessment basis and the pension coefficient) and replace approximately 70 percent of pre-disability net earnings up to a maximum of around €4,500 per month. SI benefits cover workers with temporary illness, which last longer than 12 weeks. SI benefits replace approximately 65% of the last net wage and the benefit duration is 52 weeks for individuals who have worked at least 6 months in the previous 12 months, and 26 weeks otherwise. UI benefits replace approximately 55% of the wage on the last job subject to a minimum and maximum. Unemployed below age 50 receive at most 39 weeks of regular UI benefits, job losers above age 50 can claim benefits for up to 52 weeks provided they have paid UI contributions for at least 9 years in the last 15 years.[13]

2.3.4 Austrian Social Security Data (ASSD)

In my empirical analysis, I use the Austrian Social Security Data (ASSD), which is described in Zweimüller et al. (2009). The ASSD cover the universe of private-sector employees since 1972 and contain detailed information on labor market status, earnings and demographic variables. This data set allows constructing social security benefit receipt. Based on individual's earnings records and labor market histories, I calculate old-age pensions (OA), disability pensions (DI), unemployment benefits (UI) and sick leave benefits (SI) as well as social security contributions.[14]

[13] After UI benefit exhaustion individuals can apply for "unemployment assistance" (UA), which is means-tested. UA benefits last for an indefinite period and replace around 70% of regular UI benefits. However, I do not observe UA take-up in the data.

[14] I do not directly observe pension and benefit payments but the corresponding labor market status and then construct pension and benefit payments based on my calculated benefits. I observe actual OA and DI pension payments for individuals, who receive OA or DI pensions in 2001 or start claiming after 2001. To verify my pension calculations, I compare my calculated OA and DI pensions with the actual payments for this subsample. Figures 2.42 to 2.47 in Appendix 2.E show that on average my calculated pensions track actual pensions and that there is no systematic error in my calculations across pension levels or over time.

Table 2.1: Austrian Pension Reforms

Reform	Assessment Basis	Pension Coefficient (%)	Retirement Age
Rules before 1985	indexed earnings of last 5 years	only depends on insurance years (IY) $\mathrm{PC} = \begin{cases} 50 & \text{if } 15 \leq \mathrm{IY} < 25 \\ 51 + 1.2(\mathrm{IY} - 25) & \text{if } 25 \leq \mathrm{IY} < 30 \\ 57 + 1.5(\mathrm{IY} - 30) & \text{if} \\ 79.5 & \text{if } 45 \leq \mathrm{IY} \end{cases}$	ERA: 55 women, 60 men NRA: 60 women, 65 men
1985	indexed earnings of last 10 years	reduction in pension coefficient for individuals with less than 25 insurance years ($1.9 * (\mathrm{IY})$ instead of the flat 50%).	-
1988	indexed earnings of last 15 years	-	-
1993	indexed earnings of best 15 years	pension coefficient depends on claiming age. Bonus for claiming after ERA, PC is scaled up by a factor for each month of claiming after ERA.	Increase of NRA for women from 60 to 65, but implementation starts in 2024.
1996	-	Penalty for claiming before age 56/61. Penalty depends on number of insurance years and only applies to individuals with $33 \leq \mathrm{IY} < 40$.	-
2000	-	increase of penalty for claiming before NRA (from 2 to 3 pp for each year before NRA with caps on loss)	increase of ERA from 55 to 56.5 for women, from 60 to 61.5 for men
2003	indexed earnings of best 40 years (increase by 1 year every year starting in 2004)	reduction in PC from 2 pp for each insurance year to 1.78 pp. increase in penalty for claiming early from 3 pp to 4.2 pp for each year before NRA.	increase of ERA from 56.5 to 60 for women, from 61.5 to 65 for men
2004	introduction of individual pension accounts based on life-time earnings		Corridor pension: early retirement at age 62 again possible with more than 37.5 insurance years.

I define fiscal revenue as payroll taxes minus old-age (OA) pensions, disability insurance (DI) benefits, unemployment insurance (UI) benefits, and sick-leave insurance (SI) benefits

$$\text{Fiscal Revenue} = \text{Pay roll taxes} - (\text{OA pension}+\text{DI benefits}+\text{ UI benefits}+\text{SI benefits})\,.$$

This definition of fiscal revenue treats social security as a closed system and ignores the potential effects of a pension reform on other transfer programs and other tax revenue. Ideally, I would want to include all taxes and transfers that affect the government budget constraint. However, I am limited by the data. Some taxes, like VAT, and some transfers, like social assistance, simply cannot be observed in the data. Moreover, I cannot reliably calculate the additional revenue from income taxation because labor income in the ASSD is top and bottom coded.[15] By ignoring other forms of taxation, I tend to underestimate the multipliers.

2.4 Empirical Evidence

2.4.1 Early Retirement Age

Policy Variation. The pension reforms in 2000 and 2003 increased the early retirement age (ERA) step-wise from 60 to 65 for men and from 55 to 60 for women. Figure 2.2 plots the variation in ERA by date of birth. The 2000 pension reform increased the ERA by 1.5 years and the increase was phased in by quarter of birth. For men born between October 1940 and September 1942, the ERA increased by two months every quarter of birth from 60 to 61.5. For women born between October 1945 and September 1947, the ERA increased by two months every quarter of birth from 55 to 56.5. Men with at least 45 contribution years and women with at least 40 contribution years were unaffected by this reform and could still retire at age 60 and 55 respectively. The 2000 pension reform was debated in June 2000 and put into practice in October 2000. The 2003 pension reform further increased the ERA from 61.5 to 65 for men and from 56.5 to 60 for women and the increase was again phased-in by quarter of birth. First, the ERA increased by two months for each quarter of birth for men born between January and June 1943 and for women born between January and June 1948. Then, the ERA increased by one month for each quarter of birth for men born between July 1943 and December 1952 and women born between July 1948 and December 1957. The 2003 pension reform was in parliament in June 2003 and became effective on January 2004.

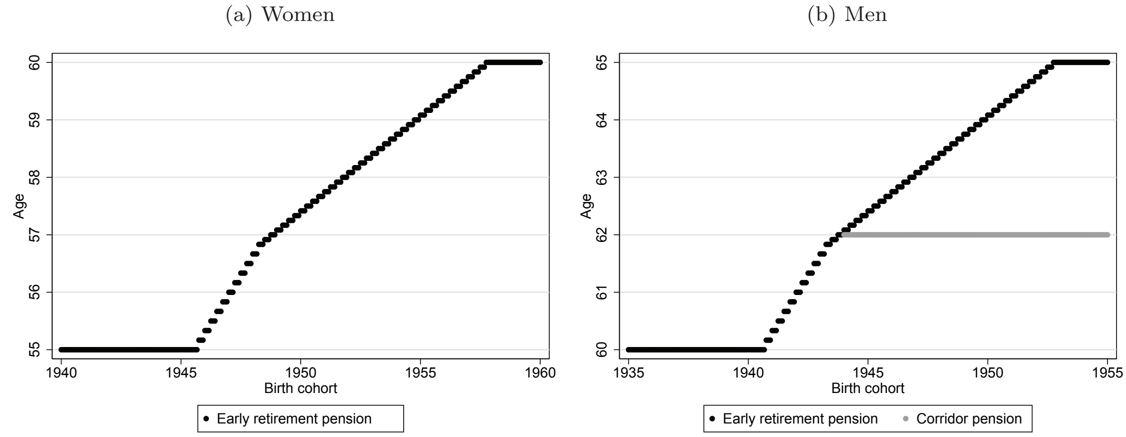
The pension reforms in 2000 and 2003 also changed other margins of the pension formula. However, for the 2000 pension reform these other changes are of minor importance for my empirical strategy. Importantly, for the 2000 pension reform the pension formula did not change if individuals claimed at their ERA. The 2003 pension reform is more challenging in this respect. In appendix 2.B, I discuss these other changes in detail.

In the main text I focus on the 2000 pension reform, which increased the ERA from 55 to 56.5 for women and from 60 to 61.5 for men. The analysis of the 2003 pension reform is in Appendix 2.C.

Sample Selection. For the 2000 pension reform, my main sample consists of all women born between 1945 and 1947 and all men born between 1940 and 1942. For the 2003 pension reform, my main sample consists of all women born between 1948 and 1957 and all men born between 1943 and 1952. In all samples, I exclude individuals who have worked in publicly-owned industries (public administration, public transportation, and education), as public sector workers are covered by a separate pension system with different eligibility rules. I further exclude self-employed individuals and individuals who have spent any time working in jobs defined as heavy labor, as they might be eligible for a special heavy labor pension. Furthermore, I exclude women with more than 40 contribution years and men with more than 45 contribution years, since they are exempt from the increase in the ERA.

[15] Pay roll taxes only apply to the uncensored part of the income distribution and I can therefore calculate them.

Figure 2.2: Early Retirement Age Variation by Quarter of Birth



Notes: This figure shows the variation in the early retirement age by date of birth. The 2000 pension reform increased the ERA for women from 55 to 56.5 and for men from 60 to 61.5 stepwise by 2 months for each quarter of birth. The 2003 pension reform further increased the ERA to 60 for women and 65 for men. The 2004 pension reform reintroduced the possibility of early retirement at age 62 for individuals with more than 37.5 insurance years ("corridor pension").

Descriptive Evidence

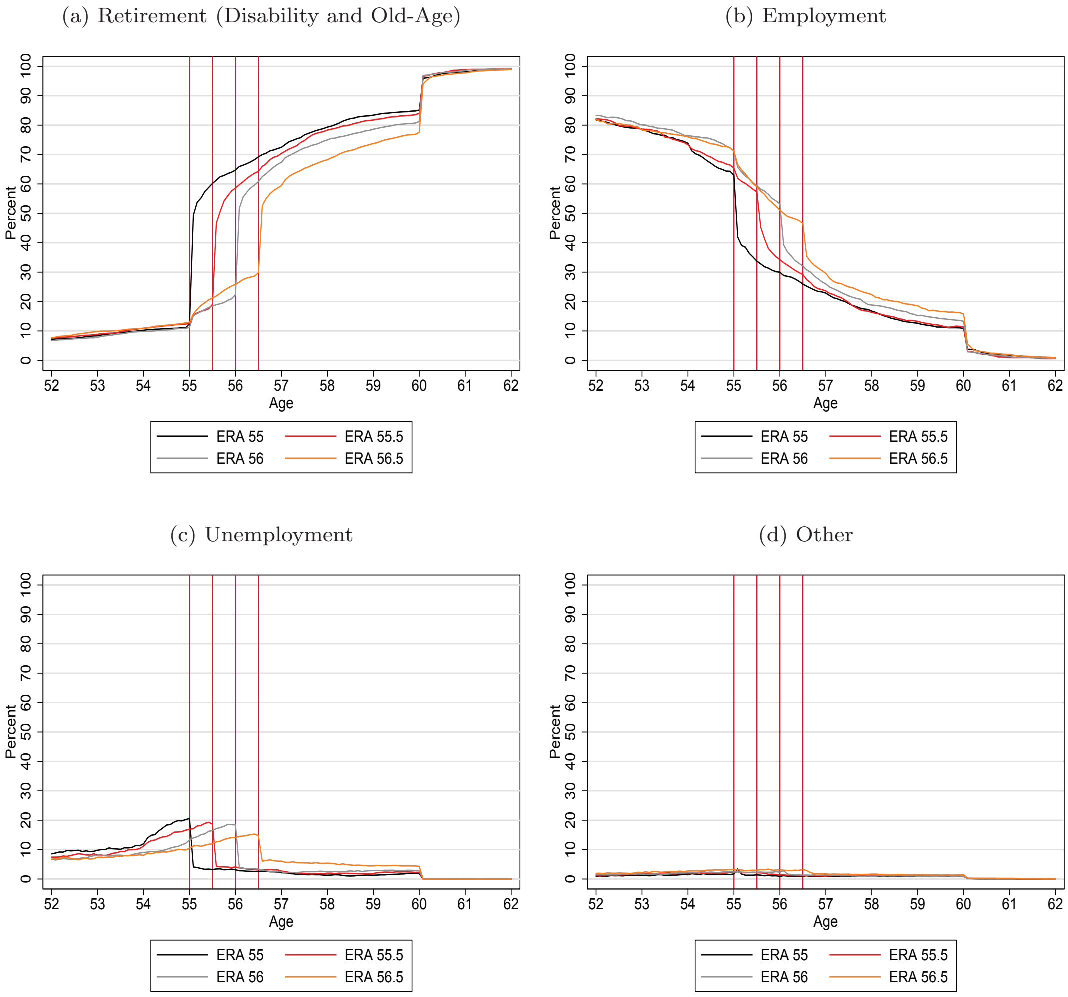
Figure 2.3 plots the percent of women in retirement, employment, unemployment and the residual category by age for different birth cohorts. The vertical lines indicate the cohort specific ERA. Panel (a) shows that around 10 percent of women are on disability benefits before age 55. Right at the ERA retirement take-up jumps up and around 50 percent of all women are in retirement. Retirement then gradually increases with age and at the NRA almost all women are retired. Panel (a) also indicates that the increase in the ERA simply shifts this retirement profile to the right.[16] Panel (b) shows that employment rates significantly drop at the ERA and the increase in ERA shifts the employment profiles to the right. Panel (c) illustrates that the unemployment rate increases to almost 20 percent in the year before the ERA and then drastically drops at the ERA. Again the increase in the ERA seems to shift this profile in parallel to the right. Panel (d) suggests that the residual category does not systematically vary across birth cohorts with different ERA.

Figure 2.4 displays the labor market - age profiles of men. Panel (a) shows that labor force participation of older men in Austria is very low. At age 59, already 50 percent of all men retired through disability pensions and only 30 percent are in employment. This is due to the generous disability insurance system with relaxed eligibility rules for individuals older than 57.[17] At the

[16] However, the figure also shows that retirement take-up increases already before the ERA. Only around a third of this increase is explained by disability insurance take-up. Hence, there are women who claim retirement prior to the new ERA. This is due to measurement error in the number of contribution years, which leads to some misclassification in eligibility rules. The number of contribution years is not directly observable and I calculate it based on labor market histories. The calculation of the contribution years is not exact because some labor market histories are censored in 1972 and I impute contribution years following the approach in Staubli and Zweimüller (2013). Moreover, the definition of contribution years is not straightforward. For instance, individuals can buy in contribution years for some of their education and I might not observe all of this. As a consequence, there are some women (men) who have actually more than 40 (45) contribution years, but I calculate less than 40 (45) contribution years for them. This problem seems to be more severe for women than for men. However, this is not a problem for my identification strategy. The misclassification reduces the absolute magnitudes of my estimates, since there is not 100 percent compliance. However, I am primarily interested in the relative size of effects (behavioral vs. mechanical fiscal effect) and the relative size is not affected by this misclassification.

[17] For a detailed discussion of the Austrian DI system see Staubli (2011); Haller et al. (2019)

Figure 2.3: Women's Labor Market Status by Age



Notes: This figure shows the labor market profiles for women born in different quarters. The vertical lines indicate the cohort specific ERA.

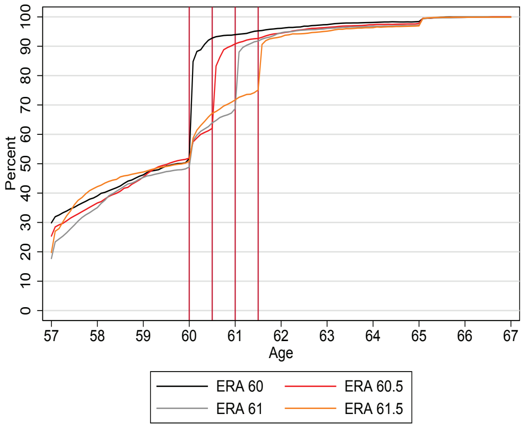
ERA around 90 percent are in retirement and less than 10 percent are still working. As for women, the increase in the ERA seems to shift all profiles to the right.

Empirical Strategy

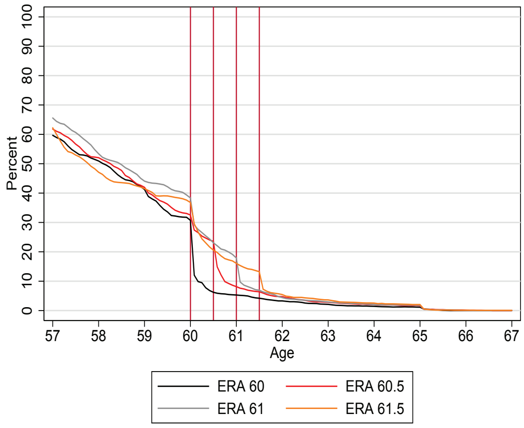
I exploit the variation in the ERA by quarter of birth in a cohort difference-in-difference specification. This approach compares younger and older cohorts, who face different ERA rules, over time. My control group consists of individuals born in the last quarter, which is not affected by the reform. Individuals in the control group can still retire at the pre-reform ERA. For the 2000 pension reform I have nine different treatment groups. Each quarter of birth with a different ERA forms a separate treatment group. I then compare the outcomes of the treatment groups and the control group at all ages between three years before the ERA and three years after. The comparison between the control group and the first treatment group identifies the effect of increasing the ERA by two months. The comparison of the second treatment group with the control group identifies the effect of increasing the ERA by four months and so on up to the ninth

Figure 2.4: Men's Labor Market Status by Age

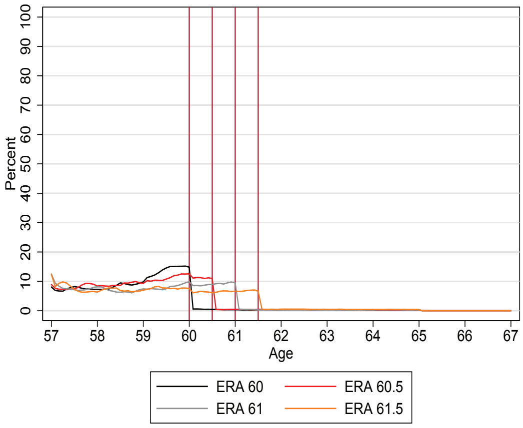
(a) Retirement (Disability and Old-Age)



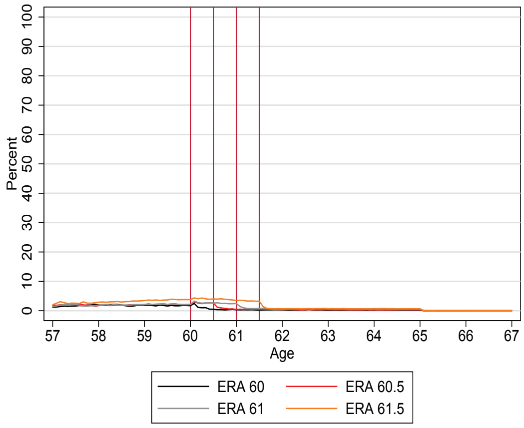
(b) Employment



(c) Unemployment



(d) Other



Notes: This figure shows the labor market profiles for men born in different quarters. The vertical lines indicate the cohort specific ERA.

treatment group, where we identify the effect of increasing the ERA by 1.5 years.[18] I implement this comparison by estimating the following regression

$$Y_{it} = \alpha + \sum_{j=1}^{9} \sum_{k=ERA-36}^{ERA+36} \beta_{kj} * Treat_{ij} * I[age_{it} = k] + \sum_{k=ERA-36}^{ERA+36} \kappa_k * I[age_{it} = k] + \sum_{j=1}^{9} Treat_{ij} + \lambda_t + \varepsilon_{it} \tag{2.11}$$

where i denotes individuals and t year-months. Y_{it} is the outcome variable of interest (such as net transfer payments, and labor supply measures like indicators for working or retirement). $I[age_{it} = k]$ are dummies for age at a monthly frequency and control for age-specific levels in the outcome variable. $Treat_{ij}$ are dummies, which indicate to which of the nine treatment groups the individual belongs. This is determined by their quarter of birth. λ_t are time dummies at monthly frequency to capture common time shocks and seasonal effects. β_{kj} then identifies the effect at age k in treatment group j.

I am interested in three main outcomes. First, how does the policy change affect fiscal revenue? For this I construct for each individual the net transfer as payroll taxes minus the sum of retirement, unemployment, disability and sick leave benefits as described in section 2.3.4. Second, I decompose the fiscal revenue effect into the behavioral and mechanical fiscal effect to get the multiplier of the reform. Third, I am interested in understanding the behavioral fiscal effect, i.e. how individuals adjust their labor market decisions in response to the change in the ERA. I construct labor market status indicators for employment, retirement, unemployment, disability pension and sick leave and also look at transitions.

Results

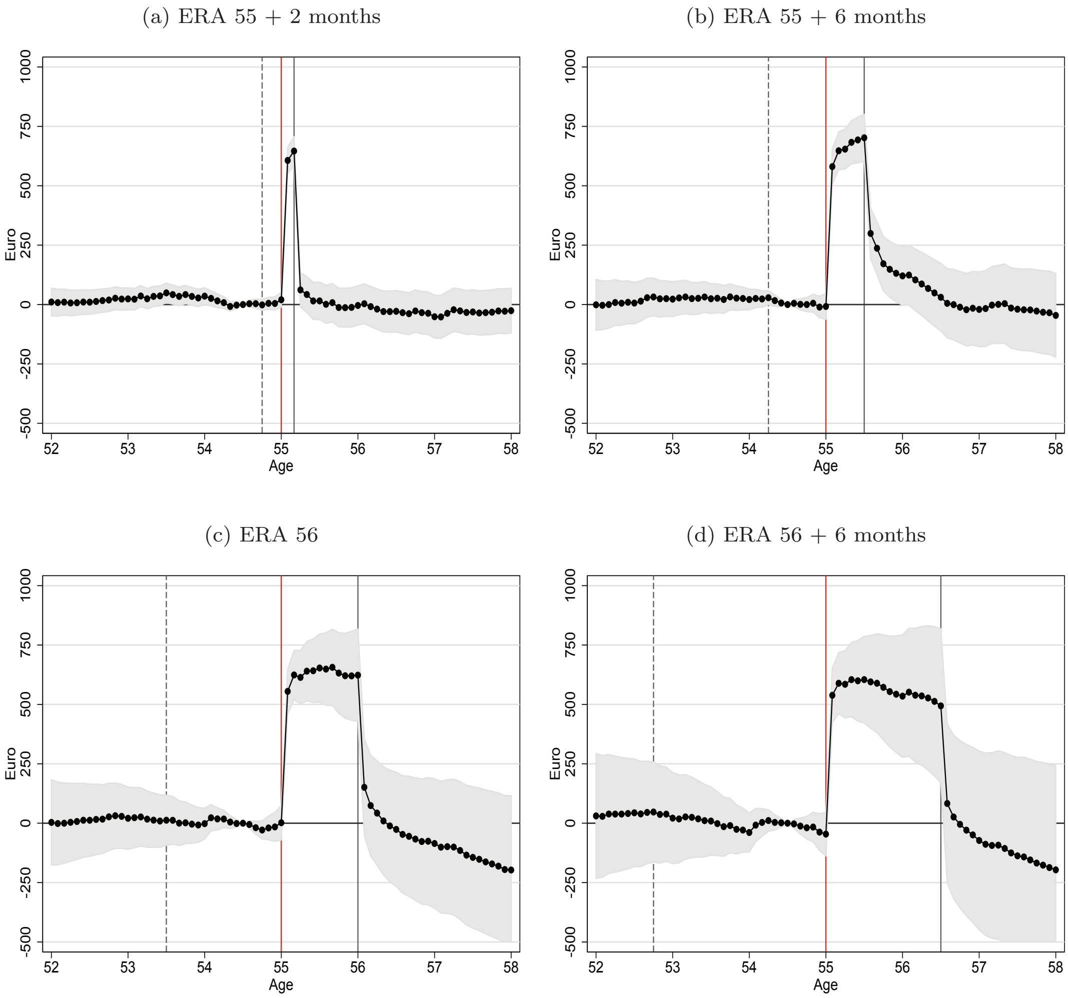
Fiscal Revenue Effect. Figure 2.5 plots the β_{kj}-coefficient estimates from regression (2.11) for the total fiscal revenue (measured in Euros) for women. Panel (a) illustrates the effect of increasing the ERA by 2 months from 55 to 55 and 2 months. Panel (b) presents the estimates for increasing the ERA by 6 months, in panel (c) the ERA is increased by one year and in panel (d) by 1.5 years. The red line indicates the pre-reform ERA at age 55, the grey solid line shows the new ERA and the dashed grey line is located at the age individuals learned about the reform. There are three main takeaways from these figures. First, increasing the ERA has a significant and positive effect on fiscal revenue. For each month of increasing the ERA the net fiscal revenue per capita increases by around 650 Euros per month. Second, there are no effects before individuals knew about the reform (at ages to the left of the dashed line), which implies that trends of the control and treatment groups are parallel pre-reform. Third, the effects are limited to the age window where the ERA increased. There are no anticipation effects before age 55. Some individuals knew more than two years in advance that their ERA is increased by more than one year (panel (d)). One could expect that individuals adjust to this increase already before age 55. For instance, with a higher ERA unemployed individuals have a stronger incentive to search for a new job, since they might run out of UI benefits before they reach the ERA. However, there is no strong evidence for such anticipation effects. Moreover, the effects vanish exactly at the new ERA and hence there are no long lasting effects beyond the new ERA.

Figure 2.6 shows the fiscal revenue effects for men. The patterns are identical to the women's patterns. Only the magnitude of the effects is slightly higher, since men tend to have higher pensions. The patterns for the other five treatment groups also look very similar, these figures can be found in Appendix 2.B.1.

Multiplier. The crucial question for welfare analysis is how much of the fiscal revenue effect is purely mechanical and how much is due to behavioral adjustments. The mechanical fiscal

[18] As a robustness check I compare only adjacent quarters of birth and run 9 separate difference-in-difference regressions. The counterfactual is then to increase the ERA by two months but starting at different ages. The results of this exercise are in Appendix 2.B.2.

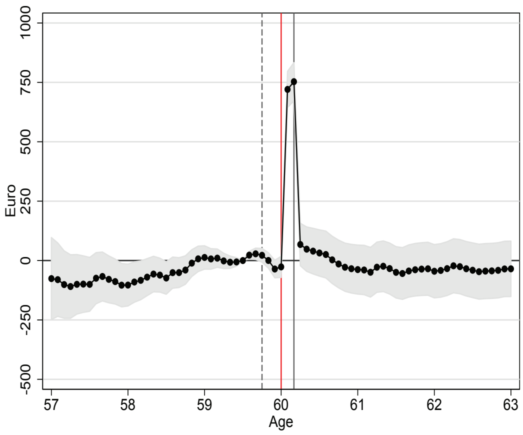
Figure 2.5: DiD Estimates Fiscal Revenue by Age for Women Reform 2000



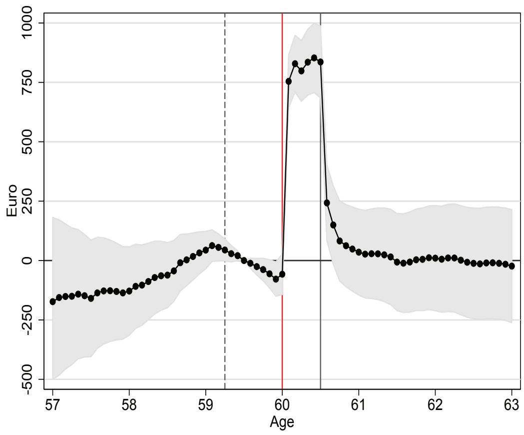
Notes: This figure plots the β_{kj}-coefficients from regression (2.11) for the total fiscal revenue (measured in Euros). Panel (a) shows the effect of increasing the ERA by 2 months, Panel (b) for a 6 month increase, Panel (c) for a one year increase and Panel (d) for a 1.5 year increase. The red line indicates the pre-reform ERA, the grey solid line shows the new ERA. The dashed grey line is located at the age individuals learned about the reform. Hence, effects between the dashed grey line and the red line could be interpreted as anticipation effects of the reform.

Figure 2.6: DiD Estimates Fiscal Revenue by Age for Men Reform 2000

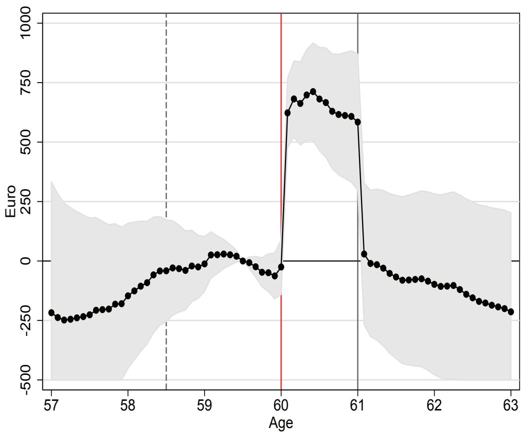
(a) ERA 60 + 2 months



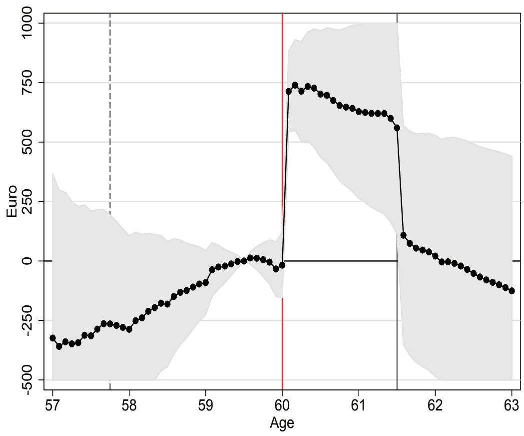
(b) ERA 60 + 6 months



(c) ERA 61



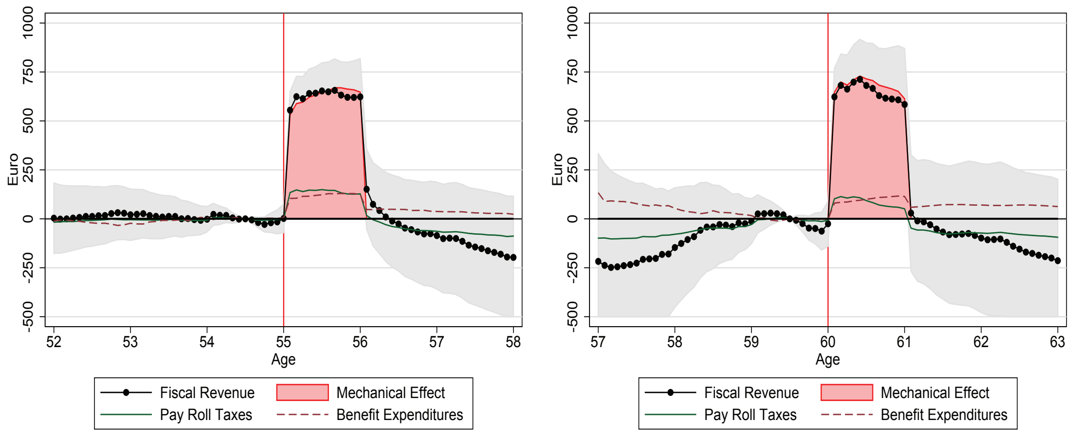
(d) ERA 61 + 6 months



Notes: This figure plots the β_{kj}-coefficients from regression (2.11) for the total fiscal revenue (measured in Euros). Panel (a) shows the effect of increasing the ERA by 2 months, Panel (b) for a 6 month increase, Panel (c) for a one year increase and Panel (d) for a 1.5 year increase. The red line indicates the pre-reform ERA, the grey solid line shows the new ERA. The dashed grey line is located at the age individuals learned about the reform. Hence, effects between the dashed grey line and the red line could be interpreted as anticipation effects of the reform.

Figure 2.7: Mechanical Effect ERA Reform 2000

(a) Women ERA 56 (b) Men ERA 61



Notes: This figure plots the estimated total fiscal revenue effect (black dots) and the mechanical fiscal effect (red area). For both women and men the fiscal revenue effect is purely mechanical. The green line plots the additional pay roll tax revenue and the maroon dashed line plots the additional benefit expenditures. The additional revenue from individuals working longer is offset by the additional expenditures from individuals substituting to UI, SI and DI benefits. These two effects cancel, leading to no additional savings from behavioral adjustments of individuals.

effect is simply the reduction in old-age pension payments between the old and new ERA. The counterfactual for the mechanical fiscal effect is that individuals would behave the same as before the reform. That is, they would stop working at the old ERA and would not receive their old-age pension until they reach the new ERA. However, individuals respond to the change in the ERA by working longer or substituting to other benefits. The behavioral fiscal effect therefore consists of the additional pay roll tax revenue minus the additional expenditures in UI, DI and SI benefits.[19]

Figure 2.7 plots the estimates for the total fiscal effect (black dots) and the mechanical effect (red area) for women with ERA 56 and men with ERA 61. The figure shows that the large and positive fiscal revenue effect of increasing the ERA is purely mechanical, implying that the behavioral fiscal effect is zero. Why are there no additional savings from individuals working longer and paying additional taxes? There is a positive fiscal effect through additional pay roll tax revenue (green line in the figure), but there are also additional expenditures from individuals substituting to UI, DI and SI benefits (red dashed line in the figure). These two effects cancel and the net fiscal effect from behavioral adjustments is zero.

Figures 2.20 to 2.23 in Appendix 2.B.1 show the decomposition of the total fiscal effect for the other treatment groups. The takeaway from these figures is that the total fiscal revenue effect is in all groups mostly driven by mechanical effect. Interestingly, at higher ERAs the negative fiscal effect of additional benefit payments starts to dominate the positive pay roll tax effect, which leads to a negative behavioral fiscal effect and a multiplier below one. Table 2.2 shows the total fiscal effect and the total effect for each treatment group. The column "Fiscal Revenue Effect" in table 2.2 is the sum of the significant β_{kj}-estimates from regression (2.11) for fiscal revenue. I

[19] I construct the mechanical fiscal effect by calculating the old-age pension expenditures in the control group between the old and new ERA and subtract the old-age pension expenditures in the treatment group in that age window. I need to subtract the old-age pension expenditures in the treatment group because some individuals in my treatment groups can still retire early if they have more than 40/45 contribution years. Without this correction I would overestimate the mechanical effect.

The alternative way to calculate the mechanical fiscal effect is to directly sum up the difference-in-difference estimates of the old-age pension expenditures between the old and the new ERA. The difference between these two approaches are minimal, the mechanical fiscal effects only differ by a few Euros.

abstract from discounting here because all effects are within a narrow time window of 1.5 years. The column "Mechanical" is the sum of the mechanical fiscal effect between the old and new ERA (red area in figure 2.7). The behavioral fiscal effect is then calculated as the difference between the fiscal revenue effect and the mechanical effect. Table 2.2 reveals increasing the ERA is an effective policy to increase fiscal revenue. A two months increase in the ERA generates an increase in net fiscal revenue of 1200 - 1400 Euros per capita. However, this total fiscal effect is purely mechanical (column two). In consequence the behavioral effect is small or even negative. This leads to multipliers that are centered around one and in some cases as low as 0.9. This means for taking one dollar away by increasing the ERA, fiscal revenue increases by around one dollar or in the worst case by only 90 cents.

The multipliers for women are decreasing with the increase in the ERA. One might worry that this is primarily driven by time trends. However, I also find multipliers around one in the robustness check in Appendix 2.B.2, where I only compare adjacent quarters of birth.

Table 2.2: Multipliers for the ERA Reform in 2000

ERA	Fiscal Revenue Effect	Mechanical	Behavioral	Multiplier (1+B/M)
Women				
ERA 55 + 2 months	1253	1120	133	1.12
ERA 55 + 4 months	3890	2474	1417	1.57
ERA 55 + 6 months	4949	3763	1185	1.32
ERA 55 + 8 months	5245	4970	275	1.06
ERA 55 + 10 months	6446	6230	216	1.03
ERA 56	7530	7578	-49	0.99
ERA 56 + 2 months	8337	8565	-228	0.97
ERA 56 + 4 months	8699	9694	-995	0.90
ERA 56 + 6 months	10069	11143	-1074	0.90
Men				
ERA 60 + 2 months	1473	1448	25	1.02
ERA 60 + 4 months	2552	3059	-507	0.83
ERA 60 + 6 months	5070	4855	216	1.04
ERA 60 + 8 months	6584	6433	152	1.02
ERA 60 + 10 months	7728	7611	117	1.02
ERA 61	7774	8173	-399	0.95
ERA 61 + 2 months	11102	10314	788	1.08
ERA 61 + 4 months	11576	10809	768	1.07
ERA 61 + 6 months	11918	11448	470	1.04

Labor Market Responses. With a higher ERA, unemployed individuals have a stronger incentive to search for a job and find employment, since they might run out of UI benefits before they reach the ERA. However, this does not happen. Individuals respond to an increase in the ERA in a very simple way. Individuals, who are employed before the old ERA, remain employed until they reach their new ERA or lose their job. Individuals, who are unemployed before the old ERA, remain unemployed until they reach their new ERA. I do not find any evidence for an increased transition from unemployment to employment at least in the short run. Figure 2.8 shows the levels for employment, unemployment and retirement. The 40 percentage points reduction in retirement is accompanied by a 20 percentage points increase in employment and a 20 percentage points increase in unemployment. Figure 2.9 plots the transitions and shows that this is driven by individuals keeping their jobs or remaining unemployed. There is no increased transition from unemployment to employment or the other way around.[20]

Welfare Implications

The analysis showed that increasing the ERA has a multiplier of around one. Hence, increasing the ERA is welfare improving only if the social value of the dollar in the hands of an early retiree is below one. The theoretical discussion in section 2.2 showed that a natural lower bound for the social value of the dollar is one. Hence, it is unlikely that increasing the ERA is welfare-enhancing.

It is still important to understand the distributional effects of increasing the ERA, i.e. to understand who retires early. Figure 2.10 plots the distribution of average income in the last 15 years (grey bars) and the share of individuals in that income bin, who retire early (red bars). The figure reveals that early retirement is prevalent across the distribution. An ERA reform therefore affects individuals from everywhere in the income distribution. This makes it harder to argue that the social value of the dollar is below one. Based on the argument in section 2.2, the average marginal utility of consumption of retirees would need to be lower than the average marginal utility of consumption in the population for the ERA reform to be welfare improving.

2.4.2 Pension Levels

An individual's pension is determined by her assessment basis multiplied with her pension coefficient. The assessment basis measures the average earnings over a specific period after applying a cap to earnings in each year. The pension coefficient is the individual's replacement rate (in percent) that is applied to the assessment basis. Before 1985 the assessment basis was the average earnings in the last 5 years. The pension reforms in 1985 and 1988 increased the assessment period step-wise from the last 5 years to the last 15 years. This makes old-age pensions on average less generous because of seniority wage profiles, however, it does not lead to a uniform cut in pension levels. Individuals across the income distribution are affected differentially. I focus on the change of the assessment period from the last 10 to the last 11 years implemented in the 1988 pension reform. This change provides a clean design as I outline in the next paragraph.

Policy Variation. In 1985, the assessment period was changed from the last 5 years to the last 10 years. This change was phased in over time. Between January and April 1985 the assessment period was either the last 5 or last 7 years, whatever was more favorable. Between May and December 1985, the assessment period was the last 7 years. In 1986, the assessment period was the last 9 years and in 1987 this was extended to the last 10 years. The 1985 pension reform also substantially reduced the pension coefficient for individuals with less than 30 insurance years. [21]

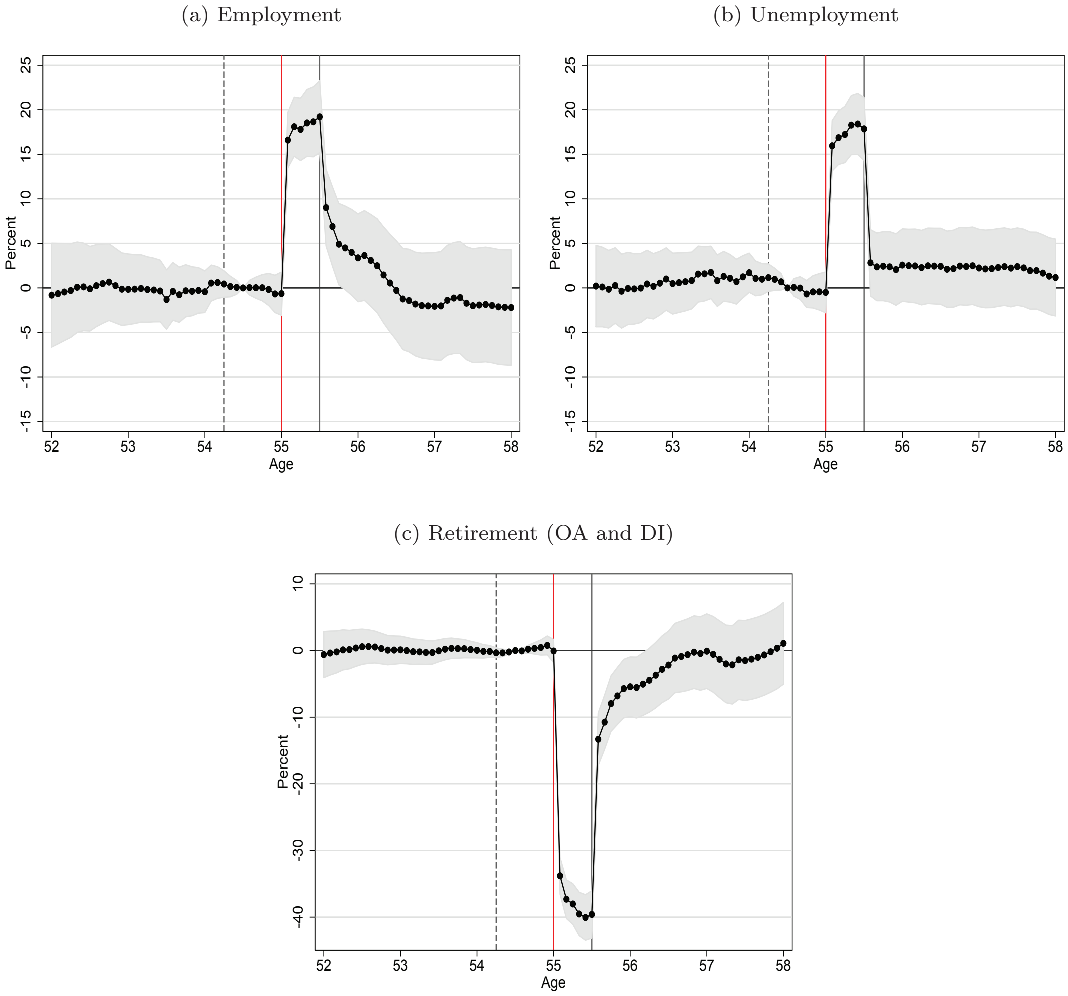
The 1988 pension reform changed the assessment period from the last 10 years to the last 15 years. This change was phased in by birth cohorts and over time. Table 2.3 describes the exact transition rules. The assessment period remains at 10 years for men born before 1.1.1928 and women born before 1.1.1933. Individuals born after these dates face an assessment period of 11 years in 1988. For men born in 1928 and women born in 1933, the assessment period remains at 11 years in the following years (unless the longer assessment period is more favorable). For the other cohorts, the assessment period increases each year by one year until they reach age 60. Only for the male cohort of 1928 and the female cohort of 1933, the rules changed once and then remained in place for the following years. I focus my analysis on these two cohorts and the 1988 pension reform, since this is the cleanest design with a clear counterfactual. [22]

[20] In the longer run, there might be a positive employment effect before the old ERA. Figures 2.24 to 2.28 in appendix 2.B show that for ERA 56 (60) and higher there is a downward sloping trend in unemployment before the ERA. It is, however, hard to tell whether this is a time trend or an effect of the reform.

[21] Pre-reform individuals with less than 30 insurance years have a flat 50% pension coefficient. After the reform, the pension coefficient is calculated as 1.9 times the number of insurance years. Hence, an individual with 15 insurance years has a pension coefficient of 50% pre-reform and after the reform her pension coefficient is 28.5%.

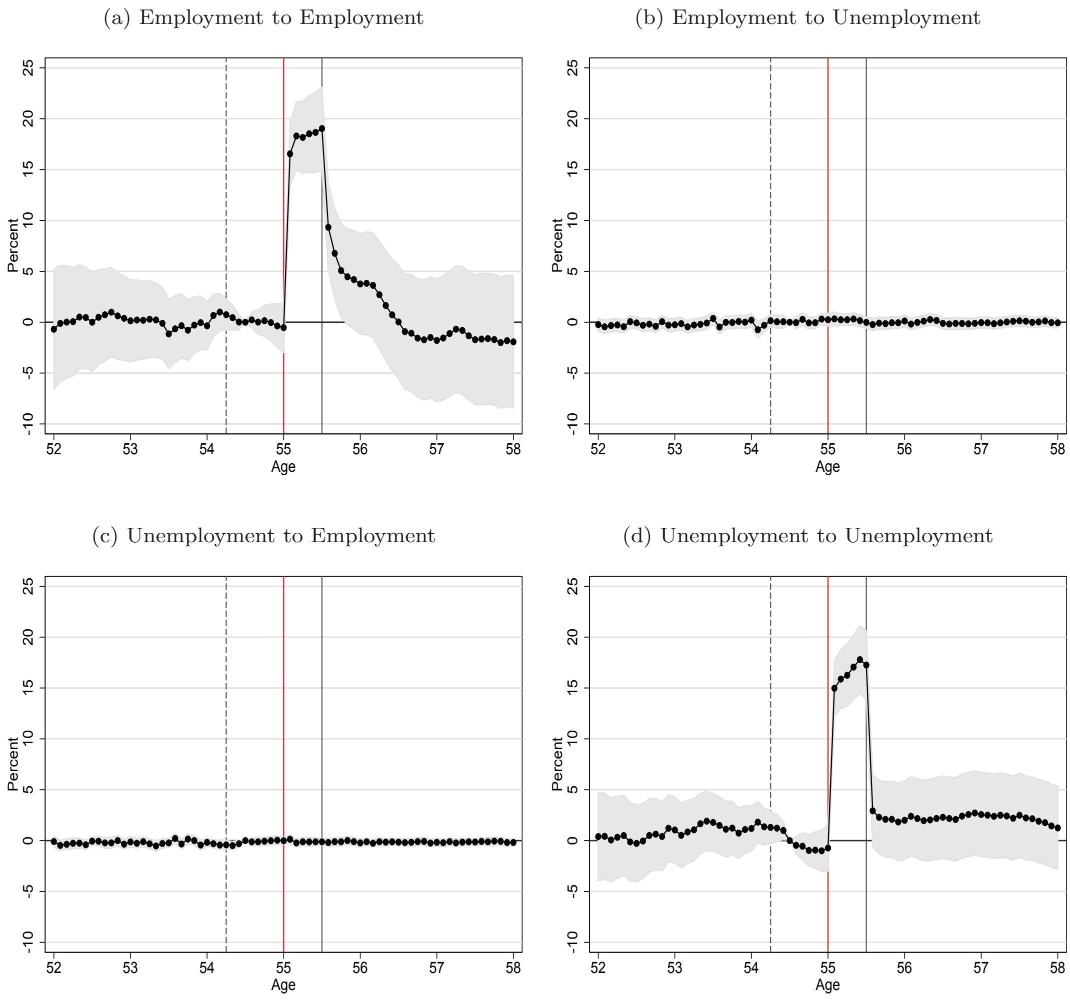
[22] DI benefits are calculated in the same way as old-age pensions, forward-looking individuals therefore have an incentive to claim DI benefits at earlier years before their assessment period increases by another year. This

Figure 2.8: DiD Estimates Labor Market Status by Age: Women ERA 55 + 6 months



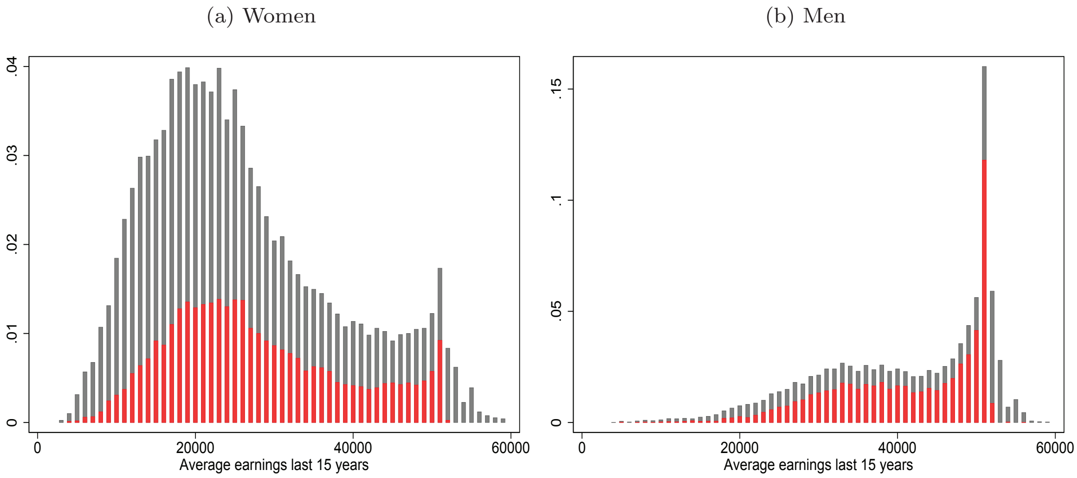
Notes: This figure shows the DiD estimates for employment, unemployment and retirement. The 40 percentage points reduction in retirement is accompanied by a 20 percentage points increase in employment and a 20 percentage points increase in unemployment.

Figure 2.9: DiD Estimates Labor Market Transitions: Women ERA 55 + 6 months



Notes: This figure shows the DiD estimates for labor market transitions.

Figure 2.10: Early Retirement across the Income Distribution



Notes: This figure plots the distribution of average income in the last 15 years (grey bars) and the share of individuals in that income bin, who retire early (red bars).

The 1988 pension reform was announced and implemented in a very short time window. In July 1987, it was announced that a new pension reform will be debated and that the reform should be implemented in 1989. However, in October 1987 the federal ministry of labor, social affairs, health and consumer protection sent out a reform proposal. The proposal passed legislation in November. The transition rules for the increase in the assessment period was not in the initial proposal and was added during the legislative process. The new rules were in place on 1.1.1988. Hence, men born in January 1928 and women born in January 1933 only learned two months in advance that they will be treated by the reform.

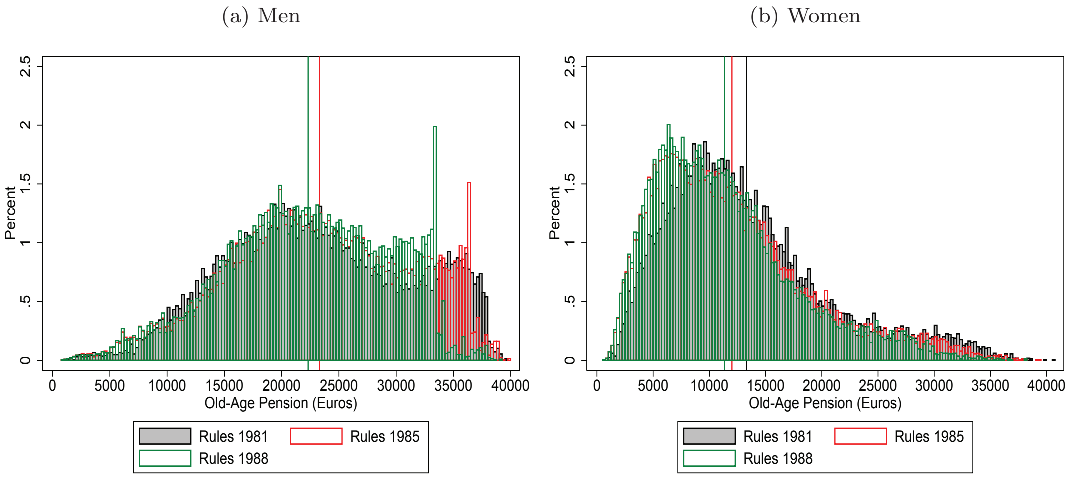
Sample Selection. My main sample consists of the male birth cohorts 1927-1928 and female birth cohorts 1932-1933. I exclude individuals who have worked in publicly-owned industries (public administration, public transportation, and education), as public sector workers are covered by a separate pension system with different eligibility rules. I further exclude self-employed individuals and individuals who have spent any time working in jobs defined as heavy labor, as they might be eligible for a special heavy labor pension. Lastly, I exclude individuals who are on DI before the reform, since they already left the labor force and are not affected by the reform.

Descriptive Evidence

Figure 2.11 plots the distribution of pension levels under the rules in 1981, 1985 and 1988. The figure shows that the increase of the assessment period from the last 5 to the last 10 to the last 15 years reduced pension levels on average but there is significant heterogeneity. Notably, men at the top of the pension distribution face a reduction in pension levels, while men at the lower end of the distribution are less affected. The effects for women are smaller because most women

anticipation effect would be interesting to estimate. However, in 1984 relaxed DI eligibility criteria were introduced. This led to strong take-up of DI after age 55 and roll-out of these more lenient rules led to very strong trends in DI take-up across birth cohorts. This makes it hard to disentangle time trends from birth cohort effects. I therefore focus on the cohorts with the fixed rules and exploit the variation in an RDD, where differential trends across birth cohorts are less of a concern.

Figure 2.11: Pension Distribution pre/post 1985 and 1988 Reform



Notes: This figure plots the distribution of pension benefits under the rules in 1981, 1985 and 1988. To isolate the effect of the change in the pension calculation, I take the male birthcohort 1927 and the female birth cohort 1932 and simulate their potential pensions under the different regimes holding their retirement behavior fixed.

are at the lower end of the pension distribution. In my main analysis I focus on the change of the assessment period from 10 to 11 years. Figure 2.12 plots the distribution of pension benefits with an assessment period of the last 10 versus the last 11 years. Men at the top of the pension distribution are strongly treated by the change in the assessment period. For women the effects are more uniform across the distribution and on average smaller. This makes it more difficult to precisely identify effects for women. The effects for men are stronger. I therefore focus on men in the main text, the results for women are in appendix 2.D.

Empirical Strategy

I exploit the variation in pension levels induced by differential assessment periods across birth cohorts in an regression-discontinuity design (RDD). The running variable is date of birth. The assessment period for men born before January 1st 1928 is 10 years, for men born between 1/1/1928 and 12/31/1928 the assessment period is 11 years. I estimate the following regression

$$Y_i = \beta D_i + f_l(bdate_i)1\{bdate_i < 1/1/1928\} + f_r(bdate_i)1\{bdate_i \geq 1/1/1928\} + \varepsilon_i, \qquad (2.12)$$

where $D_i = 1\{bdate_i \geq 1/1/1928\}$ is an indicator for individual i being born after January 1st 1928, $f_l(\cdot)$ and $f_r(\cdot)$ are flexible functions to capture trends in the outcome variable by date of birth. I am again interested in the total fiscal effect of the reform, the decomposition of this effect into the behavioral and mechanical part, and understanding the labor market responses of individuals.[23]

Results

Labor Market Responses. Figure 2.13 shows that the reduction in pension levels has significant effects on retirement take-up at age 60. Individuals to the left of the cutoff have an assessment

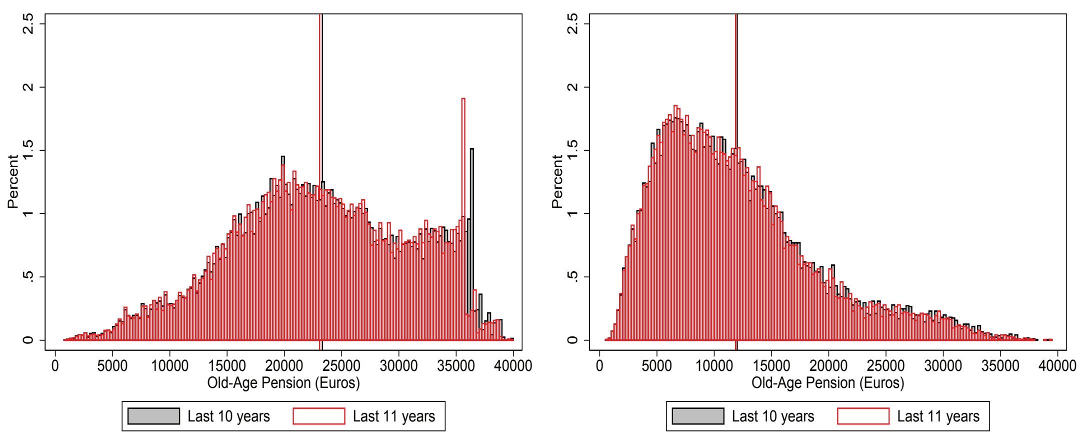
[23]Figure 2.36 in appendix 2.D shows that the number of observations are not perfectly smooth around January for all birth cohorts. I discuss in appendix 2.D why this seems not to be a problem for my RDD.

Table 2.3: Phase in Pension Reform in 1988

Year	Men born	Women born	Assessment period	If more favorable
1988	until 1927	until 1932	120 months	132 months
	after 1928	after 1933	132 months	
1989	until 1927	until 1932	120 months	144 months
	in 1928	in 1933	132 months	144 months
	after 1929	after 1934	144 months	
1990	until 1927	until 1932	120 months	156 months
	in 1928	in 1933	132 months	156 months
	in 1929	in 1934	144 months	156 months
	after 1930	after 1935	156 months	
1991	until 1927	until 1932	120 months	168 months
	in 1928	in 1933	132 months	168 months
	in 1929	in 1934	144 months	168 months
	in 1930	in 1935	156 months	168 months
	after 1931	after 1936	168 months	
1992	until 1927	until 1932	120 months	180 months
	in 1928	in 1933	132 months	180 months
	in 1929	in 1934	144 months	180 months
	in 1930	in 1935	156 months	180 months
	in 1931	in 1936	168 months	180 months
	after 1932	after 1937	180 months	

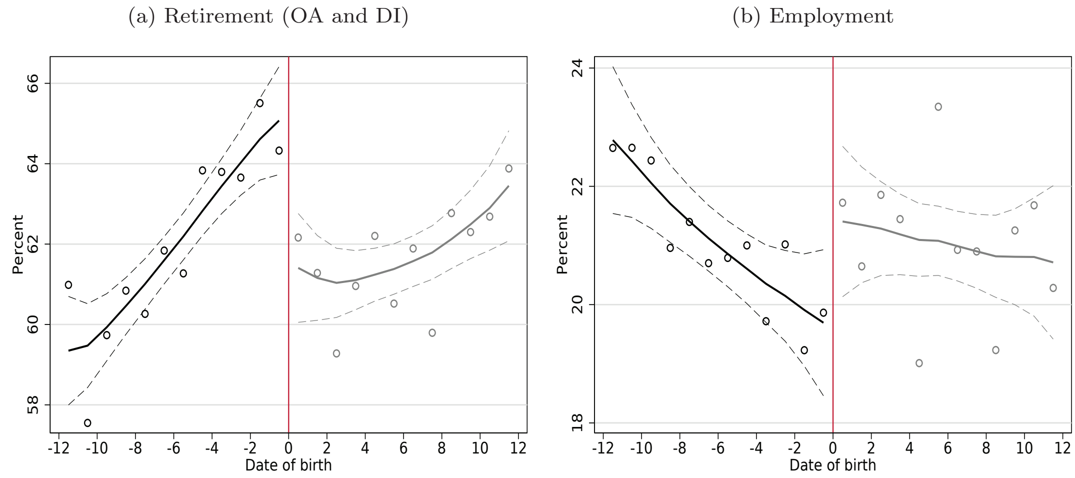
Figure 2.12: Pension Distribution with Assessment Period last 10 vs. last 11 years

(a) Men (b) Women



Notes: This figure plots the distribution of pension benefits with assessment period last 10 years versus last 11 years. To isolate the effect of the change in the assessment period, I take the male birthcohort 1927 and the female birth cohort 1932 and simulate their potential pensions under the different regimes holding their retirement behavior fixed. Hence, the shift in the distribution illustrates the mechanical effect of the reform. The vertical lines represent the means.

Figure 2.13: Retirement and Employment at Age 60



Notes: This figure shows the average retirement and employment rates at age 60. The fitted lines are local linear polynomials with a bandwidth of 8 months.

basis of 10 years, individuals to the right of the cutoff have an assessment basis of 11 years. This leads to a reduction of around 1.25 percent in pensions on average. The lower pensions go hand-in-hand with a reduction of 2 percentage points in retirement take-up at age 60 (panel (a)) and to a less precisely estimated increase in employment of around 2 percentage points (panel (b)). There are no effects on UI or SI take-up. Even though treatment intensity is not very strong with a 1.25 percent reduction in pension levels at the cutoff, individuals react in their labor supply decision.

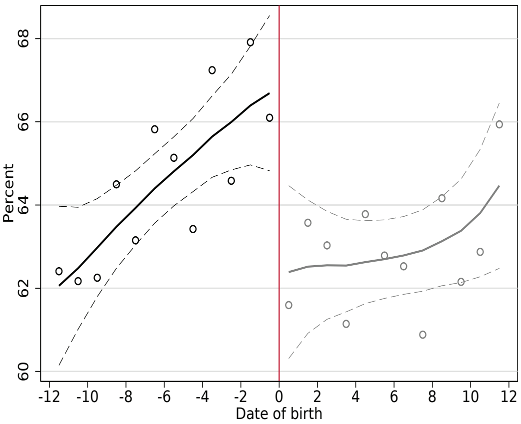
The increase in the assessment period from 10 to 11 years does not lead to a uniform cut in pension levels. The corresponding pension reduction varies by earnings history. Individuals with flat wage profiles are not treated by the change, while individuals with seniority wage profiles face a reduction in pension levels due to the reform. This naturally creates placebo and treatment groups. To exploit this, I calculate for each individual the potential pension he would get with an assessment period of 10 and 11 years given his earnings history at age 59.5. Based on these potential pensions I define two groups: (i) a treatment group composed of individuals, who experience a reduction in pensions of at least 1.5% and (ii) a placebo group composed of individuals, who have roughly equal pensions in both regimes (change in pensions is between 0 and 0.25%). This definition is arbitrary and based on sample size considerations.[24] Figure 2.14 shows retirement and employment rates at age 60 for these two groups. The figure reveals that the retirement and employment effect we observe in the whole sample is driven by the treatment group. For the treatment group (individuals with a change in pensions of more than 1.5%), retirement at age 60 drops from 66% to 62% at the cutoff (panel (a)). This reduction in retirement rates by 4 percentage points is offset by a 4 percentage points increase in employment (panel (b)). Panels (c) and (d) show that there is no significant effect in the placebo group.

Figure 2.15 plots the RD estimates at each age between 50 and 85. There are no effects before age 59. Individuals just learn about the reform at age 59 and hence this is another placebo test for the validity of the RDD. There is a significant reduction in retirement at age 60 and a corresponding increase in employment. For ages 61 to 65 the point estimates still suggest a lasting effect on retirement and employment. However, these effects are not precisely estimated and not

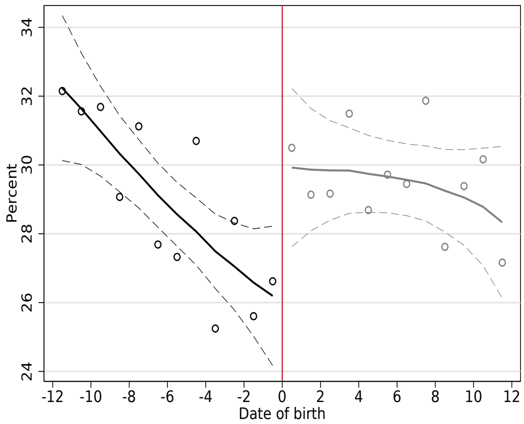
[24] Roughly 25% of all individuals experience a decline in pensions of more than 1.5%. Taking a higher cutoff value would significantly reduce the sample size.

Figure 2.14: Employment and Retirement at Age 60

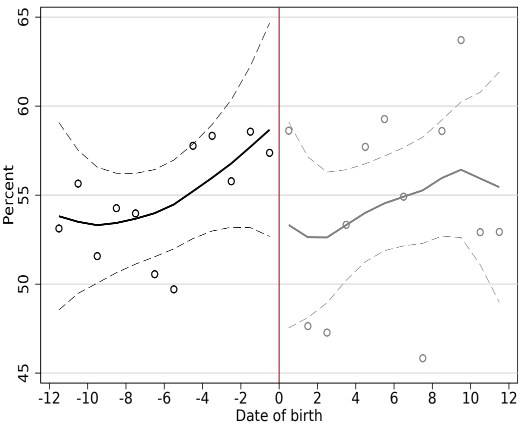
(a) Treatment group: Retirement (OA and DI)



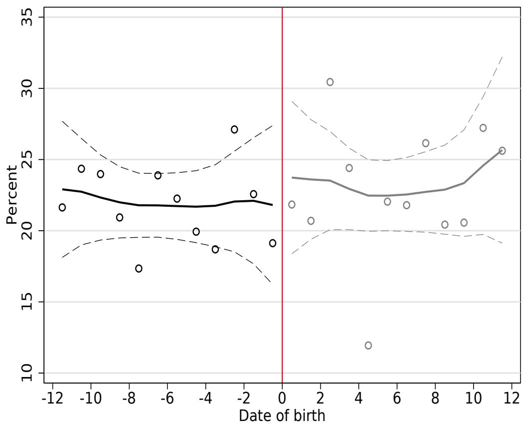
(b) Treatment group: Employment



(c) Placebo group: Retirement (OA and DI)



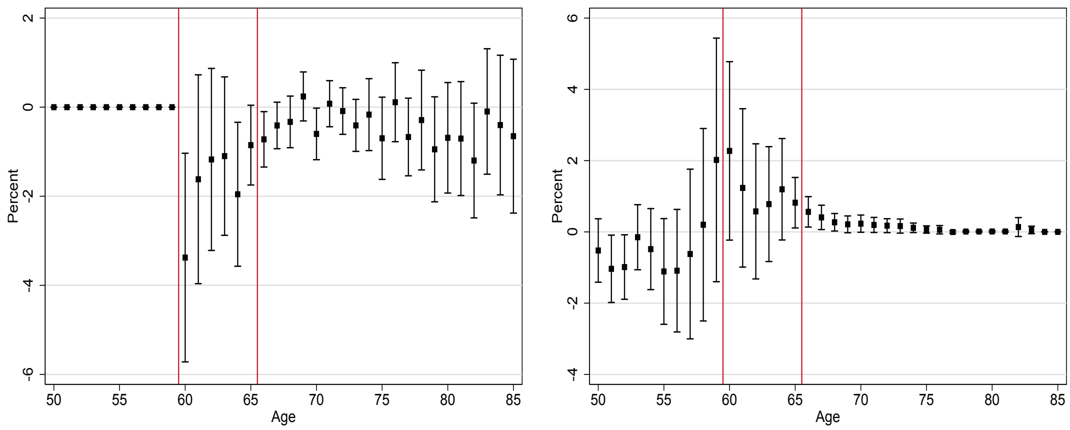
(d) Placebo group: Employment



Notes: This figure shows the average retirement and employment rates at age 60. The fitted lines are local linear polynomials with a bandwidth of 8 months. The treatement group is defined as individuals who potentially loose more than 1.5 percent in their OA pension if the assessment period is changed from 10 to 11 years. This potential loss is measured at age 59.5. The placebo group consists of individuals, who experience a loss of less than 0.25 percent.

Figure 2.15: RD Estimates by Age: Men

(a) Retirement (OA and DI) (b) Employment



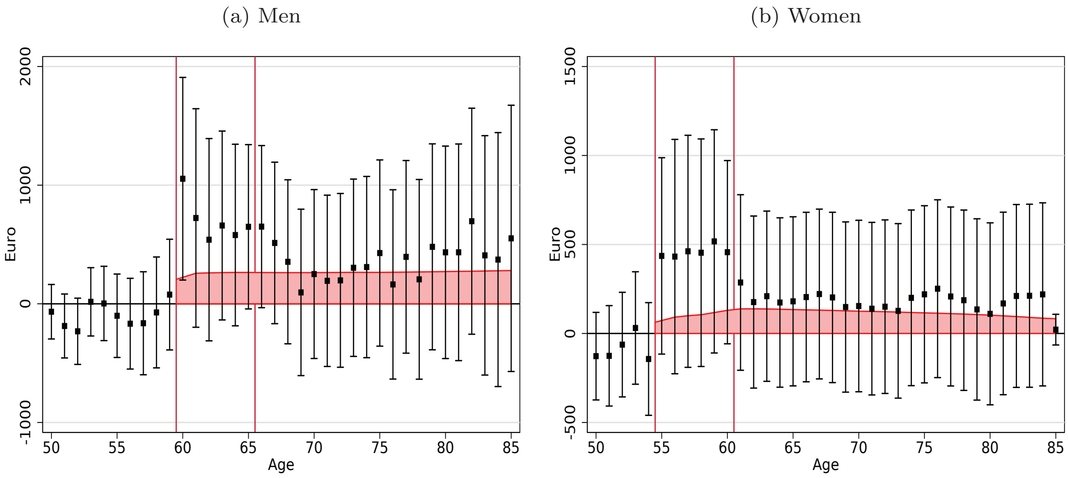
Notes: This figure plots the RD estimates at each age between 50 and 85 based on local linear regressions with a bandwith of 8 months.

statistically different from zero. After the normal retirement age at 65, the point estimates are close to zero.

Fiscal Revenue Effect and Multiplier. Figure 2.15 already indicates that the policy change induced behavioral change. Figure 2.16 shows how these labor supply effects translate to fiscal revenue effects. Figure 2.16 plots the RD estimates for fiscal revenue at each age between 50 and 85 for men and women. The red area indicates the mechanical fiscal effect of the reform. Before the early retirement age there is no mechanical effect. There are also no effects on fiscal revenue as we would expect if the RD is valid (individuals did not yet know about the reform at these ages). Between the early and normal retirement age, the estimated total fiscal effect is larger than the mechanical fiscal effect. After the normal retirement age the total fiscal effect very closely follows the mechanical effect. The difference between the total fiscal effect and the mechanical fiscal effect is the behavioral fiscal effect. Hence, the figure corresponds to what one would expect from the labor supply responses. There is a behavioral fiscal effect from individuals delaying retirement and working longer. After the normal retirement age, when everyone is retired, only the mechanical effect of the reform is left. This is a consistent pattern for both men and women but the effects are not precisely estimated. However, this is not surprising since treatment intensity is relatively low with an average reduction in pension levels of 1.25 percent for men (with a median change of 1.5 percent) and 1.2 percent for women (with a median change of 1.2 percent).

Based on these estimates I construct the present value of the total fiscal effect and the present value of the mechanical fiscal effect at age 60. I discount the effects with an interest rate of two percent and then add up the estimates from age 60 to age 85. Above the normal retirement age I set the fiscal revenue estimates equal to the mechanical effect, since they are almost identical. Not doing this would lead to higher multipliers. Table 2.4 shows the present value of the total fiscal revenue effect, of the total mechanical fiscal effect and the corresponding multiplier. For men the multiplier of the reform is 1.48. For women the multiplier is 1.84. Table 2.7 in Appendix shows multipliers for different discount rates and for different bandwidths of the local linear regressions. For lower bandwidths and higher discount rates multipliers tend to be higher.

Figure 2.16: RD Estimates by Age: Fiscal Effect



Notes: This figure plots the RD estimates for fiscal revenue by age (black squares with 95 CI, based on local linear regressions with bandwidth 8 months). The red area indicates the mechanical fiscal effect of the reform. Between the ERA and NRA the estimated total fiscal effect is larger than the mechanical fiscal effect. After the NRA the total fiscal effect very closely follows the mechanical effect. Hence, there is a behavioral fiscal effect (difference btw. total and mechanical) between ERA and NRA. After the NRA, when everyone is retired, only the mechanical effect of the reform is left.

Table 2.4: Multiplier Benefit Generosity Reform 1988

Group	Fiscal Revenue Effect	Mechanical	Behavioral	Multiplier (1+B/M)
Men	7995	5408	2587	1.48
Women	4735	2578	2157	1.84

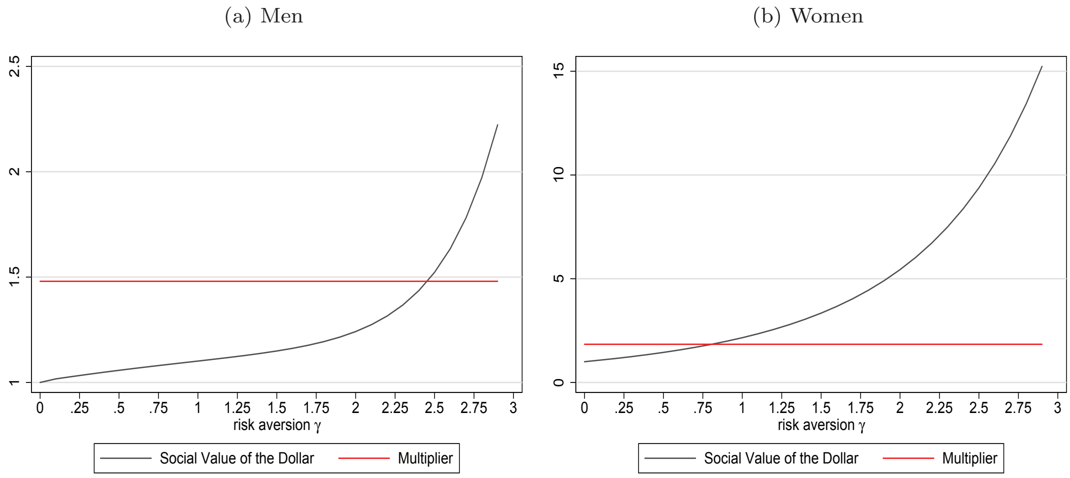
Welfare Implications

The relative comparison between the ERA reform and the pension level reform reveals a clear pattern. The multipliers of a reduction in pension levels are 50 percent larger than the multipliers of increasing the ERA. Additionally, the reduction in pension levels mostly affects individuals at the top of the income distribution while the ERA reform affects individuals across the income distribution. Based on the discussion in section 2.2, this implies for a planner with preferences for redistribution that the reduction in pension levels has a lower social value of the dollar compared to increasing the ERA because the pension level reform targets higher income individuals. Hence, a planner with preferences for redistribution clearly favors the pension level reform over the ERA reform, because it has higher multipliers and comes at a lower social cost (lower social value of the dollar).

The absolute welfare effect of the pension level reform is positive if the social value of the dollar is less than 1.48 for men and at less than 1.84 for women. To illustrate the magnitude of the social value of the dollar, I parameterize the model. In summary, I assume a standard isoelastic (CRRA) utility function and that the fiscal savings from the pension reform are lump-sum redistributed in the working age population, i.e. λ corresponds to the average marginal utility of consumption of working age individuals. Furthermore, I assume that consumption equals income since consumption cannot be observed in the data. This potentially overestimates the social value of the dollar. Working age individuals tend to save (consume less than their income), while retirees tend to dissave (consume more than their pension payments). Hence, assuming consumption equals income overestimates the marginal utility of consumption of retirees (numerator of social value of the dollar) and underestimates the marginal utility of consumption of working age individuals (denominator of social value of the dollar). Appendix 2.A.5 provides a detailed discussion of this parametrization.

With these assumptions, I can directly calculate the social value of the dollar as a function of the risk aversion parameter γ. Figure 2.17 plots the social value of the dollar and the multiplier of the 1988 pension reform for men and women. Panel (a) shows that reducing pension levels of men is welfare-enhancing if risk aversion is below 2.4, i.e. the multiplier is larger than the social value of the dollar. Hence, this parametrization implies that the reform is welfare improving for reasonable values of risk aversion .[25] Panel (b) shows reducing pension levels of women is welfare-reducing if risk-aversion is above 0.75 even though women have a larger multiplier than men. The different welfare implications for men and women arise because the pension levels of women are significantly lower than the pension levels of men, which implies a much larger social value of the dollar for women. However, individual pension income of women in 1988 in Austria is probably a poor approximation for their consumption. Income at the household level would be a better predictor but cannot be observed in my data. For men individual income is a better approximation for household resources in that time.

Figure 2.17: Welfare Effects of Reducing Pension Levels



Notes: This figure plots the social value of the dollar and the multiplier of the 1988 pension reform. The social value of the dollar is based on the parameterization of the utility function (additive separable CRRA utility function) as detailed in Appendix 2.A.5. Reducing pension levels of men is welfare-enhancing (multiplier is larger than social value of the dollar) if risk aversion is below 2.4. For women, reducing pension levels is welfare-reducing if risk-aversion is above 0.75. The large difference between men and women arises because the pension levels of women are significantly lower than the pension levels of men, which implies a much larger social value of the dollar for women.

[25] Estimates from the literature suggest that the coefficient of relative risk aversion is below 2, Chetty (2006b) finds an upper bound of $\gamma < 1.78$.

2.5 Conclusion

This paper shows that the behavioral fiscal multiplier is central for welfare evaluation of pension reforms. The behavioral fiscal multiplier, the total fiscal effect relative to the mechanical fiscal effect, can be readily estimated with reduced-form methods and provides the benchmark against which to judge the social value of the dollar. Exploiting a series of pension reforms in Austria, I find that increasing the early retirement age has a multiplier of 1 and reducing pension levels has a multiplier of 1.5. This implies that increasing the Austrian early retirement age has not been welfare-enhancing – unless one thinks that $1 in the hands of an early retiree has a lower social value than $1 in public funds. By contrast, reducing pension levels is welfare improving – provided that taking $1 away from a retiree is associated with a social loss smaller than $1.5. For a standard parametrization of the utility function I find that the social loss is smaller than 1.5 for reasonable values of risk aversion and hence reducing pension levels was welfare-improving. The low multiplier of increasing the early retirement age arises because the additional social security contributions paid by workers spending more time in employment are neutralized by additional expenditures on unemployment benefits. In contrast, reducing pension levels induced some workers to stay longer in employment without triggering substitution to other welfare benefits. My empirical analysis illustrated my framework in the Austrian context. Needless to say that the estimated multiplier depends on the particular context. If my framework is applied to reforms in other countries, the welfare implications can be very different depending on the labor market responses of affected workers.

The more general message of my analysis is twofold. First, the size of the behavioral multiplier crucially depends on the extent to which a particular pension reform generates spillovers to other pension reforms. Second, pension reforms generate high multipliers if older workers face a labor market with favorable job opportunities. For instance, increasing retirement ages does not generate large multipliers if older workers cannot find or keep their jobs. To some degree, labor market opportunities for older workers are a policy parameter. Hence, policy makers can influence multipliers and the effectiveness of reforms. Potential labor market policies to achieve this are active labor market policies targeting older unemployed individuals, providing financial incentives for firms to keep older workers employed (e.g. reduced social security contributions) or increased job protection to keep older workers in employment. The effectiveness of such policies is an important topic for future research, especially the role of firms seems understudied in this respect. Another important topic for future research is to relate the social value of the dollar to observable moments in the data. In the unemployment literature, there are exciting new approaches on this frontier (e.g. Landais and Spinnewijn (2019) and Hendren (2017)), which could also be applied in the retirement context.

2.A Theory

2.A.1 Derivation Optimal Benefit Function

This section derives the formula for the optimal benefit function in (2.9). The derivation establishes the differentiability of the government's objective function and that the first order condition (2.6) holds for any optimal benefit function. The derivation exploits the powerful "differentiable sandwich lemma" from Clausen and Strub (2016), who generalize the envelope theorems in Milgrom and Segal (2002). For the derivation, I impose three technical assumptions. First, I assume that the utility function $U_i(C,\Pi,X)$ is twice continuously differentiable in consumption $c(x^t)$ with $\frac{\partial U_i(.)}{\partial c_t(x_t)} > 0$ and $\frac{\partial U_i(.)}{\partial c_t(x_t)} \to \infty$ for $c_t(x_t) \to 0$ and $\frac{\partial^2 U_i(.)}{\partial c_t(x_t)^2} \leq 0$. Second, I assume the existence of a solution to the agent's problem that can be represented by a Lagrangian. Third, I assume the planner's budget constraint is differentiable in b.

We can solve agent i's optimization problem in (2.1)-(2.3) with the following Lagrangian

$$\begin{aligned}\mathcal{L}_i(C,\Pi,\gamma,\eta) \quad = \quad & U_i(C,\Pi,X) \qquad (2.13)\\ & -E\left[\sum_{t=0}^{T-1}\gamma_{i,t+1}\left(a_{t+1}-(1+r_t)a_t-y_t(x^t)+\tau(x^t)-b(x^t)+c_t(x^t)+q(p_t(x^t))\right)\right]\\ & -E\left[\sum_{t=0}^{T-1}\eta_{i,t+1}\left(s_{t+1}-f\left[s^t,\pi_t(x^t),\varepsilon_t\right]\right)\right].\end{aligned}$$

Let a solution to this problem be denoted by C_i^*,Π_i^* and the corresponding Lagrange multipliers be denoted by $\gamma_i^*=\{\gamma_{i,j+1}\}_{j=0}^{T-1}$ and $\eta^*=\{\eta_{i,j+1}\}_{j=0}^{T-1}$. The optimal consumption choice solves

$$\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x_t)} = \gamma_{i,t+1}. \qquad (2.14)$$

The government's optimization problem is to choose functions $b(\cdot)$.[26] We can express the planner's objective function as $W(b)=\int_{i\in I}\omega_i V_i(b)=\int_{i\in I}\omega_i\mathcal{L}_\mathrm{i}(C(b),\Pi(b),\gamma(b),\eta(b))di$, where $C(b),\Pi(b)$ denote the optimal choices of the agent for a given benefit function b and $\gamma(b),\eta(b)$ are the corresponding Lagrange multipliers. The Lagrangian of the planner's problem in (2.4) and (2.5) is given by

$$\mathcal{L}_{\mathrm{SP}}(b)=\int_{i\in I}\omega_i\mathcal{L}_\mathrm{i}(C(b),\Pi(b),\gamma(b),\eta(b))di+\lambda\left(G(b)-\bar{G}\right). \qquad (2.15)$$

Suppose b^* is an optimal solution to the planner's problem. To establish differentiability of the planner's objective function I construct a lower and upper support function and then apply the differentiable sandwich lemma. As an upper support function I take $C(b)=W(b^*)$, where $W(b^*)$ is the welfare associated with the optimal benefit function b^*. By definition we have $W(b^*)\geq W(b)\ \forall b$.This upper support function is therefore simply a constant and $C'(b)=\delta W(b^*;h)=0$. The lower support function is given by $L(b)=\int_{i\in I}\omega_i\mathcal{L}_\mathrm{i}(C(b^*),\Pi(b^*),\gamma(b^*),\eta(b^*))di+\lambda\left(G(b)-\bar{G}\right)$. $\mathcal{L}_\mathrm{i}(C(b^*),\Pi(b^*),\gamma(b^*),\eta(b^*))$ is the indirect utility of the agent, holding his behavior for benefit function b^* fixed. This corresponds to the idea of a lazy decision maker that uses a completely unresponsive policy rule as in Benveniste and Scheinkman (1979). We have $\mathcal{L}_\mathrm{i}(C(b^*),\Pi(b^*),\gamma(b^*),\eta(b^*))\leq\mathcal{L}_\mathrm{i}(C(b),\Pi(b),\gamma(b),\eta(b))\ \forall b$. Therefore, $L(b)$ is a lower support function. Since I assume that the planner's budget constraint is differentiable, $L(b)$ is differentiable and the derivative is given by

$$L'(b)=\int_{i\in I}\omega_i E\left[\sum_{t=0}^{T-1}\gamma_{i,t+1}^*h(x_t)\right]di+\lambda\delta G(b^*;h) \qquad (2.16)$$

[26] For notational convenience I suppress the tax function $\tau(\cdot)$. Optimization of the tax function would add an additional first order condition identical with the one for the benefit function, just with opposite sign.

By the differentiable sandwich lemma of Clausen and Strub (2016), we have $\delta W(b^*; h) = C'(b) = L'(b)$. Using $C'(b) = 0$ and (2.16) we get

$$\delta W(b^*; h) = \int_{i \in I} \omega_i E\left[\sum_{t=0}^{T-1} \gamma^*_{i,t+1} h(x_t)\right] di + \lambda \delta G(b^*; h) = 0. \tag{2.17}$$

Using (2.14) and

$$\delta G(b; h) = \sum_{t=0}^{T-1} [1 + r_t]^{-t} E[-h(x_t)] + \int \sum_{t=0}^{T-1} \int [1 + r]^{-t} \left[-b(x^t)\right] \delta\mu(x^t; h) dx^t di \tag{2.18}$$

yields the result in (2.9).

2.A.2 Lower Bound for the Social Value of the Dollar

To derive a lower bound for the social value of the dollar we first need to bound λ. For this, suppose that the tax system is such that we cannot improve welfare through lump-sum transfers, i.e. equation (2.9) holds for all lump-sum transfers $\overline{h}$.[27] In this case, we have

$$\lambda = \frac{\frac{1}{M(\overline{h})} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} \overline{h}\right] di}{1 + \frac{B(\overline{h})}{M(\overline{h})}}. \tag{2.19}$$

Moreover, if we assume that for lump-sum transfers the behavioral response is small (income effects are small), i.e. $1 + \frac{B(\overline{h})}{M(\overline{h})} \approx 1$, we have

$$\lambda = \frac{1}{M(\overline{h})} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C, \Pi, X)}{\partial c_t(x^t)} \overline{h}\right] di \tag{2.20}$$

and λ corresponds to the average marginal utility of consumption in the population. If there are income effects, individuals will adjust their labor supply in response to the transfers and we have $1 + \frac{B(\overline{h})}{M(\overline{h})} \geq 1$. As a consequence we have

$$\lambda \leq \frac{1}{M(\overline{h})} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C, \Pi, X)}{\partial c_t(x^t)} \overline{h}\right] di. \tag{2.21}$$

For the social value of the dollar, this implies

$$\frac{\frac{1}{M(h)} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t)\right] di}{\lambda} \geq \frac{\frac{1}{M(h)} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t)\right] di}{\frac{1}{M(\overline{h})} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} \overline{h}\right] di}, \tag{2.22}$$

where $\overline{h}$ is the lump-sum transfer, which would redistribute the mechanical effect from the reform $M(h)$ equally across all agents and periods and hence we have $M(h) = M(\overline{h})$. If we think that the marginal utility of individuals affected by the reform is larger than the average marginal utility in the population and assume equal welfare weights for all individuals, then

$$\text{Social Value of the Dollar} \geq \frac{\frac{1}{M(h)} \int E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t)\right] di}{\frac{1}{M(\overline{h})} \int E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} \overline{h}\right] di} \geq 1. \tag{2.23}$$

[27] Actually, it is sufficient to assume that increasing lump-sum taxes is not welfare-enhancing. In this case, we have $\lambda \leq \frac{\frac{1}{M(\overline{h})} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} \overline{h}\right] di}{1+\frac{B(\overline{h})}{M(\overline{h})}}$ for all lump-sum taxes $\overline{h}$ and the argument still goes through.

For instance, this is the case if we assume that the utility function is concave in consumption (falling marginal utility) and that the reform targets individuals, who have below average consumption. These are all reasonable assumptions for pension reforms and hence a natural lower bound for the social value of the dollar is 1 dollar.

The assumption of equal welfare weights is not crucial. The argument goes through if the welfare weights are such that a transfer to retirees is socially more valuable than a transfer to all individuals.

2.A.3 Comparison to the Baily-Chetty Formula (Optimal Unemployment Insurance)

The famous Baily-Chetty formula for optimal unemployment insurance is a special case of my formula in equation (2.9). The stylized Baily-Chetty formula is given by

$$\frac{v'(c^u)}{u'(c^e)} = 1 + \varepsilon$$

where $\varepsilon = \frac{\partial D}{\partial b}\frac{b}{D}$, denotes the elasticity of unemployment duration D with respect to unemployment benefit generosity b.

The RHS of this formula exactly corresponds to my RHS term in (2.9). By definition we have $\varepsilon = \frac{\partial D}{\partial b}\frac{b}{D}$. Since individuals can only respond by adjusting their search effort and this affects fiscal expenditures through altered unemployment duration ∂D, the behavioral fiscal effect is given by $B = \partial D * b$. The mechanical fiscal effect is given by $M = \partial b * D$. Hence, the elasticity captures the behavioral over mechanical fiscal effect in this model, i.e. $\varepsilon = \frac{\partial D}{\partial b}\frac{b}{D} = \frac{B}{M}$.

In this stylized job search model individuals have a utility function for being employed $u(c^e)$ and a utility function for being unemployed $v(c^u)$. Both utility functions only depend on consumption levels and taxes are lump-sum. The cost of taxation λ is simply the marginal utility of the tax-payer and given by $u'(c^e)$. The direct welfare effect of changing unemployment benefit generosity in this model is given by $E_h\left[\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x_t)}\right] = \frac{1}{\Delta M(h)}\int \omega_i E_i\left[\sum_{t=0}^{T-1}\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)}h(x^t)\right]di = \frac{1}{D\partial b}Dv'(c^u)\partial b = v'(c^u)$. Hence, my formula applied to this stylized model exactly delivers the Baily-Chetty formula.

2.A.4 Multiple Generations

The model in the main text treats pensions systems as if each generation pays for their own pensions during their working life. However, an important aspect of pensions is inter-generational redistribution. I show that even with multiple generations it is key to estimate the multiplier of a pension reform in one generation. To introduce multiple generations, let there be a stream of generations indexed by $j \in \{1, 2, \ldots\}$ and each generation consists of a continuum of agents indexed by $i \in I_j$. Agents in each generation j solve the same maximization problem as in equations (2.1)-(2.3), but the constraints and objective functions can be generation specific.

Overlapping Generations: In the classical overlapping generations setup, the currently young generation $j+1$ finances the pensions of the currently old generation j. The problem of the planner is to choose benefit and tax functions for each generation j. The planner puts a welfare weight g_j on each generation j and solves the following problem

$$\max_{\{b_j(\cdot),\tau_j(\cdot)\}_{j\geq 1}} W(b,\tau) = \sum_{j\geq 1} g_j \int_{I_j} \omega_i V_i di \tag{2.24}$$

subject to

$$\sum_{t\geq 0}[1+r_t]^{-t}E_{j+1}\left[\tau_{j+1}(x^t)\right] - \sum_{t\geq 0}[1+r_t]^{-t}E_j\left[b_j(x^t)\right] \geq 0\ \forall j \in \{1,2,\ldots\}. \tag{2.25}$$

For each generation there is a separate budget restriction requiring that the present value of benefit payments to the currently old generation equals the present value of the tax revenues from the young generation. The optimal benefit function of generation j then solves

$$\frac{g_j \frac{1}{M(h)} \int_{I_j} \omega_i E_i \left[\sum_{t\geq 0} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t) \right] di}{\lambda_{j+1}} = 1 + \frac{B_j(h)}{M_j(h)} \tag{2.26}$$

where $B_j(h)$ is the behavioral fiscal effect of generation j over their life cycle and $M_j(h)$ is the mechanical fiscal effect of generation j. Hence, the RHS of this optimality condition (2.26) is identical to the RHS of optimality condition (2.9) in the single generation setup. The only difference to the single generation version is the interpretation of the LHS. The LHS measures the social value of a dollar in the hand of the currently old generation j relative to the social value of a dollar in the hand of the currently young generation $j+1$. To make this more transparent, assume that the planner redistributes the savings from the pension reform with lump-sum transfers to generation $j+1$. In this case, the optimal benefit function solves

$$\frac{g_j}{g_{j+1}} \frac{\frac{1}{M(h)} \int_{I_j} \omega_i E_i \left[\sum_{t\geq 0} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t) \right] di}{\int_{I_{j+1}} \omega_i E_i \left[\sum_{t\geq 0} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} \right] di} = 1 + \frac{B_j(h)}{M_j(h)}. \tag{2.27}$$

General Setup: The budget restriction in the overlapping generations framework above is too restrictive in the sense that the planner can smooth expenditures and revenue across multiple generations. In this more flexible formulation the planner solves

$$\max_{b_j(\cdot),\tau_j(\cdot)} W(b,\tau) = \sum_{j\geq 1} g_j \int \omega_i V_i di \tag{2.28}$$

$$G(b,\tau) = \sum_{j\geq 1} \sum_{t\geq 0} [1+r_t]^{-t} E\left[\tau_j(x^t) - b_j(x^t)\right] \geq 0. \tag{2.29}$$

The optimal benefit formula then solves

$$\frac{g_j \frac{1}{M(h)} \int_{I_j} \omega_i E_i \left[\sum_{t\geq 0} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t) \right] di}{\lambda} = 1 + \frac{B_j(h)}{M_j(h)} \tag{2.30}$$

and is therefore identical to the optimal benefit formula in the main text (except that there is the additional welfare weight g_i for the generation on the LHS). Importantly, in the multiple generation setup we also need to estimate the multiplier of the reform within one generation in the same way as in the one generation model in the main text.

2.A.5 Parametrization Model

The social value of the dollar consists of three parts: (i) the marginal utility of consumption, (ii) welfare weights and (iii) the social value of public funds λ. Hence, I need to make assumptions on these three margins.

First, I parameterize the utility function. I assume that utility is additively separable over time and additively separable in consumption and the other choices. I denote the utility of consumption in period t by $u(c_t)$ and the utility of the other choices by $\psi(\Pi, X)$. Hence, expected life-time utility is given by

$$U_i(C,\Pi,X) = E\left[\sum_{t=0}^{T-1} \left(\beta^t u(c_t) \right) - \psi(\Pi,X) \right]. \tag{2.31}$$

Moreover, I assume that the utility function is isoelastic, i.e.

$$u(c_t) = \begin{cases} \frac{c_t^{1-\gamma}-1}{1-\gamma} & \gamma \geq 1 \,\&\, \gamma > 0 \\ ln(c_t) & \gamma = 1 \end{cases}, \tag{2.32}$$

where γ denotes the coefficient of relative risk aversion.

Second, I assume a utilitarian planner, i.e. every individual gets the same welfare weight $\omega_i = 1 \, \forall i$.

Third, I need to pin down the social value of public funds. Following the discussion in Appendix 2.A.2, I assume that welfare cannot be improved through lump-sum transfers to working age individuals (younger than the ERA). This implies that

$$\lambda = \frac{1}{1+\frac{B(\bar{h})}{M(\bar{h})}} \int E_i \left[\sum_{t=0}^{ERA} \left(\beta^t u'(c_t)\bar{h} \right) \right] di \tag{2.33}$$

holds for any small lump-sum transfer $\bar{h}$. If we further assume that income effects are small, i.e. $1+\frac{B(\bar{h})}{M(\bar{h})} \approx 1$, we get that

$$\lambda \approx \int E_i \left[\sum_{t=0}^{ERA} \left(\beta^t u'(c_t) \right) \right] di. \tag{2.34}$$

The social value of the dollar is then given by

$$\text{Social Value of the Dollar} = \frac{\frac{1}{M} \int E_i \left[\sum_{t=ERA}^{T-1} \left(\beta^t u'(c_t) h_{it} \right) \right] di}{\int E_i \left[\sum_{t=0}^{ERA} \left(\beta^t u'(c_t) \right) \right] di} \tag{2.35}$$

where h_{it} is the reduction in individual i's pension in period t because of the reform and M is the mechanical effect of the reform (the sum of h_{it}).

In my data, consumption is not observable. As an approximation I use income instead of consumption. Hence, for retirees I set consumption equal to pension payments, i.e. $c_t = b_t$. For working age individuals I set consumption equal to labor income, i.e. $c_t = w_t$. This potentially overestimates the social value of the dollar. Working age individuals tend to save, i.e. $c_t \leq w_t$, and hence $u'(w_t) \leq u'(c_t)$. Retirees tend to dissave, i.e. $c_t \geq b_t$, and hence $u'(b_t) \geq u'(c_t)$. Therefore, we expect that

$$\frac{\frac{1}{M} \int E_i \left[\sum_{t=ERA}^{T-1} \left(\beta^t u'(c_t) h_{it} \right) \right] di}{\int E_i \left[\sum_{t=0}^{ERA} \left(\beta^t u'(c_t) \right) \right] di} \leq \frac{\frac{1}{M} \int E_i \left[\sum_{t=ERA}^{T-1} \left(\beta^t u'(b_t) h_{it} \right) \right] di}{\int E_i \left[\sum_{t=0}^{ERA} \left(\beta^t u'(w_t) \right) \right] di} \equiv \text{USVD} \tag{2.36}$$

holds and that my implementation provides an upper bound for the social value of the dollar (USVD). Lastly, I assume no discounting $\beta = 1$.This provides a further upper bound on the social value of the dollar (since the numerator of the social value of the dollar would be relatively smaller with discounting).

Implementation for 1988 Pension Level Reform. To implement the upper bound on the social value of the dollar (USVD as defined in (2.36)) for the 1988 pension reform, I calculate the mechanical loss h_{it} for each individual in the control group (men born in 1927 and women born in 1932) by calculating their old-age pensions with an assessment period of 10 and 11 years and then take the difference between the two.

Based on the CRRA specification I calculate the marginal utility of each individual for different values of γ, multiply it by h_{it} and take the average across individuals and periods. This average is then divided by the mechanical effect M (the average of h_{it} over individuals and periods). For the denominator, I take the earnings distribution of working-age individuals in the year 1988 and calculate the average marginal utility of consumption for this earnings distribution for different values of γ.

2.A.6 Extensions

The insight that the multiplier of a reform is central for welfare evaluation relies on three critical assumptions. First, I assume that individuals optimize a consistent utility function and the social planner respects the preferences of the individuals. Second, I assume that reforms are small. Third, I abstract from general equilibrium effects and externalities of pensions reforms. I discuss here how deviations from these three assumptions change the welfare evaluation. In general, any deviation from these three assumptions leads to an additional term on the LHS of equation (2.9) but does not change the RHS. Hence, in any case we need to know the multiplier of the reform.

General Equilibrium Effects

Allowing for price changes does not alter the logic of the welfare evaluation. With perfect competition the price adjustments only have a direct welfare effect through the mechanical effect of the price changes. With general equilibrium effects, the optimal benefit function formula becomes

$$\frac{\frac{1}{M(h)}\int_{I_j}\omega_i E_i\left[\sum_{t\geq 0}\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)}h(x^t)\right]di}{\lambda}+\gamma=1+\frac{B(h)}{M(h)} \tag{2.37}$$

where $\gamma=\frac{\frac{1}{M(h)}\int_{I_j}\omega_i E_i\left[\sum_{t\geq 0}\frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)}dP(x^t)\right]di}{\lambda}$ and $dP(x^t)$ measures the price change due to the reform. Furthermore, $B(h)$ is evaluated at the new prices, while $M(h)$ is evaluated at the old prices. The sign of γ depends on the price changes. The general equilibrium effects of pension reforms we might worry about are changes in wages and interest rates. If a pension reform induces individuals to retire later and save more we might expect that interest rates fall (since there is more capital). This affects capital returns of individuals and the planner's budget constraint through the discounting (this is captured in the behavioral fiscal effect $B(h)$). The effect on wages is not a priori clear. It could be that the additional capital makes workers more productive and therefore wages increase. It could also be that the additional workers in the market reduce wages (increased labor supply). In the context of Austria it is unlikely that a pension reform affects interest rates, since Austria is a small open economy and does not even set their own monetary policy.

Non-marginal Changes

The optimal benefit formula only holds for marginal changes. However, real-world reforms are never truly marginal. In this section I discuss the welfare effect of discrete changes. Suppose there are two different benefit functions $b_0(\cdot)$ and $b_1(\cdot)$, where $b_1(x^t)=b_0(x^t)+h(x^t)$. The welfare effect of the discrete change from $b_0(\cdot)$ to $b_1(\cdot)$ is given by

$$\Delta W = W(b_1,\tau)-W(b_0,\tau) \tag{2.38}$$

$$= \int\omega_i\left[V_i(b_1)-V_i(b_0)\right]di+\lambda\left(G(b_1,\tau)-G(b_0,\tau)\right) \tag{2.39}$$

where I assumed that $\lambda_0=\lambda_1=\lambda$. $G(b_1,\tau)-G(b_0,\tau)$ measures the total fiscal effect of moving from benefit function $b_0(\cdot)$ to $b_1(\cdot)$. Define $G(b_k)=\int\sum_{t\geq 0}\left[1+r_t\right]^{-t}\int\left[\left(\tau(x)-b_k(x)\right)\mu_k(x)\right]dxdi$, where $b_k(x)$ denotes the benefit payment for state history x in regime $k=\{0,1\}$ and $\mu_k(x)$ is the distribution of state histories in regime k. The state distribution $\mu_k(x)$ depends on the behavior of individuals. The total fiscal effect can then again be decomposed into a behavioral and mechanical effect:

$$G(b_1) - G(b_0) = \int \sum_{t\geq 0} [1+r_t]^{-t} \int \left[\underbrace{\Delta b_0(x)\mu_1(x)}_{\text{mechanical}} + \underbrace{(\tau(x) - b_0(x))\,\Delta\mu_0(x)}_{\text{behavioral}} \right] dxdi \quad (2.40)$$

where $\Delta b_0(x) := b_1(x) - b_0(x)$ and $\Delta\mu_0(x) := \mu_1(x) - \mu_0(x)$. The mechanical effect is now only slightly differently defined as

$$\Delta M(h) = \int \sum_{t\geq 0} [1+r_t]^{-t} \int \Delta b_0(x)\mu_1(x) dxdi. \quad (2.41)$$

The mechanical fiscal effect is now evaluated at the post reform state distribution, but this is still straightforward to implement empirically. The behavioral fiscal effect is given by

$$\Delta B(h) = \int \sum_{t\geq 0} [1+r_t]^{-t} \int (\tau(x) - b_0(x))\,\Delta\mu_0(x) dxdi. \quad (2.42)$$

For discrete changes the envelope theorem fails and behavioral adjustments have first order welfare effects. The direct welfare effect is given by

$$\begin{aligned} \int \omega_i \left[V_i(b_1) - V_i(b_0)\right] di &= \int \omega_i \left[V_i(b_0+h) - V_i(b_0)\right] di \quad (2.43) \\ &= \int \omega_i \left[\delta V_i(b_0;h) + \frac{1}{2!}\delta^2 V_i(b_0;h,h) + \ldots + \frac{1}{(k-1)!}\delta^{k-1} V_i(b_0;h,\ldots,h) + R_k\right] di \end{aligned}$$

where the second line uses a Taylor approximation and the remainder term is $R_k = \frac{1}{(k-1)!}\int_0^1 (1-t)^{k-1}\delta^k V_i(b_0+th;h,\ldots,h)dt$. Using $\delta V_i(b_0;h) = E_i\left[\sum_{t\geq 0} \frac{\partial U_i C,\Pi,X)}{\partial c_t(x^t)} h(x^t)\right]$ we can write the discrete welfare change as

$$\Delta W = \frac{\frac{1}{\Delta M(h)} \int \omega_i E_i \left[\sum_{t=0}^{T-1} \frac{\partial U_i(C,\Pi,X)}{\partial c_t(x^t)} h(x^t)\right] di}{\lambda} + \gamma - \left(1 + \frac{\Delta B(h)}{\Delta M(h)}\right) \quad (2.44)$$

where $\gamma = \frac{1}{\lambda \Delta M(h)}\left(\frac{1}{2!}\delta^2 V_i(b_0;h,h) + \ldots + \frac{1}{(k-1)!}\delta^{k-1} V_i(b_0;h,\ldots,h) + R_k\right)$. With non-marginal changes the social value of the dollar term has an additional component γ, since behavioral adjustments have first order welfare effects. Nevertheless, the multiplier of the reform is still a key ingredient for welfare evaluation.

Behavioral Biases

A recent and growing literature documents behavioral elements in retirement decisions (Behaghel and Blau, 2012; Goda et al., 2015; Brown et al., 2016; Cribb et al., 2016; Merkle et al., 2017; Seibold, 2019). This evidence raises the question how the welfare evaluation changes in presence of behavioral biases. Generally, behavioral biases induce a potential conflict between the planner's and the agents objectives. The behavioral welfare literature makes the distinction between decision utility and true or "experienced" utility. If the two do not coincide, agents do not maximize their true utility. As a consequence the logic of the envelope theorem fails and behavioral responses have first order welfare effects. Hence, there is an additional term in the direct welfare effect that measures the bias correction of behavioral responses. This is analogous to the effects of behavioral elements in optimal tax frameworks as in Farhi and Gabaix (2015) and Bernheim and Taubinsky (2018). The crucial question in models with behavioral elements is: What is the true utility and consequently what is the right welfare criterion? This discussion is interesting and important. However, this paper makes no progress on that frontier. I simply assume that true preferences exist and are known to the planner. My analysis here follows Farhi and Gabaix (2015) and I simply adjust notation to my setup.

Let $U(\theta)$ denote the true or "experienced" life-time utility for choices θ.[28] However, choices are no longer necessarily made by maximizing the true utility function $U(\theta)$. Agents could maximize another (biased) decision utility function or fail to maximize completely. The choice function θ incorporates all these potential behavioral aspects. As in Farhi and Gabaix (2015), the only restriction I impose is that the agent's budget restriction is binding. That is, $K(b,I) := \sum_{t=0}^{T-1}[1+r_t]^{-t} E\left[y_t(x^t) - \tau(x^t) + b(x^t) - c_t(x^t) - q(p_t(x^t))\right] - I = 0$, where I denotes the initial endowment. The indirect utility function is denoted by $V(b,I) = U(\theta(b,I))$. The government's objective function is then given by

$$W(b) = V(b,I) + \lambda\left(G(b) - \bar{G}\right)$$

where $G(b)$ is government revenue and defined as in the standard model.

A change of the benefit function with increment h has a welfare effect of $\delta W(b;h) = \delta V(b,I;h) + \lambda\delta G(b;h)$ and the optimal benefit function sets $\delta W(b;h) = 0$ for all h. This expression can be rewritten using a behavioral version of Roy's identity to get

$$\frac{V_I}{\lambda} + \gamma = 1 + \frac{B(h)}{M(h)} \tag{2.45}$$

where

$$\gamma = \frac{\delta(\theta;h)}{\lambda M(h)}\left(\frac{U_\theta}{V_I} - K_\theta\right) \tag{2.46}$$

is the bias-correction effect. The RHS is the same as in the standard model. The first term on the LHS, $\frac{V_I}{\lambda}$, is analogous to the standard model. However, in the model with optimizing agents I could express it in terms of marginal utilities of consumption through the agent's first order conditions. The new term γ captures the first order welfare effect of behavioral adjustments. The expression $\frac{U_\theta}{V_I} - K_\theta$ in γ measures the welfare cost of the behavioral biases. Farhi and Gabaix (2015) call this term the "*behavioral wedge*" and Bernheim and Taubinsky (2018) refer to this as the "*price-metric measure of bias*". Intuitively, $\frac{U_\theta}{V_I} - K_\theta$ is the difference between the money-metric of marginal utilities, $\frac{U_\theta}{V_I}$, and the prices K_θ and therefore measures the degree of misoptimization. With rational optimizing agents this behavioral wedge is zero.[29] If agents fail to optimize their true preferences, γ is non-zero and is determined by the behavioral wedge multiplied with the reform induced change in behavior, $\delta(\theta;h)$. The sign of bias-correction term, γ, depends on the exact biases present and whether the reform corrects the sub-optimal behavior or amplifies the biases.

The two most prominent behavioral biases in the retirement context are myopia and statutory retirement ages as reference-points. In case of myopic behavior, individuals save too little, work not enough and retire too early.[30] Hence, a policy change that induces more savings, later retirement and so on has a positive bias correction term and reduces the direct welfare effect of taking a dollar away from retirees. If retirement ages serve as reference points, it is not clear what the true utility is or should be. The additional complication is that the planner can set the statutory retirement ages and might therefore be able to shift the reference point. How to evaluate welfare effects in this context is an open question and an interesting avenue for future research.

[28] To save notation θ includes all choices, i.e. $\theta = \{C, \Pi\}$, and I suppress that the utility function might depend on the state history X.

[29] Formally, a rational agent solves $\max_\theta U(\theta)$ subject to $K = \sum_{t=0}^{T-1}[1+r_t]^{-t} E\left[y_t(x^t) - \tau(x^t) + b(x^t) - c_t(x^t) - q(p_t(x^t))\right] - I = 0$, which yields first order condition $U_\theta = V_I K_\theta$. Therefore, $\gamma = 0$.

[30] The consensus in the literature is to model myopic behavior with hyperbolic discounting and assume that the true utility function uses exponential discounting. However, Bernheim (2009, 2016) argues that it is not clear whether this is really a bias/mistake. It could also be interpreted as a present focus, i.e. living in the moment, that should not be corrected by the planner.

2.B Early Retirement Age Reform 2000

Other Policy Variation 2000 Pension Reform: The 2000 pension reform also changed other margins but less dramatically than the ERA and these changes do not systematically vary by quarter of birth. The reform increased the penalty for claiming retirement benefits before the normal retirement age (NRA). Before the reform the pension coefficient is reduced by 2 percentage points for each year of claiming retirement benefits before the NRA. This penalty is capped at 10 percentage points. Moreover, the reduction can be at most 15 percent of the pension coefficient before the penalty.[31] The 2000 pension reform increases the penalty from 2 to 3 percentage points for each year of claiming before the NRA. The maximal penalty is slightly increased from 10 percentage points to 10.5 percentage points and the rule that the pension coefficient with penalty can at most be 15 percent lower than without penalty remains in place. However, the new penalty only applies to men born after September 1942 and to women born after September 1947. For men born before September 1942 and women born before September 1947, there was no change in the pension formula if they claimed at the earliest possible age. If they claimed at older ages the change in the penalty from 2 to 3 percentage points is phased in by quarter of birth. This phase-in led to small differences in the replacement rate between quarter of births for claiming after the ERA. However, the differences in the replacement rate between two adjacent quarters of birth are around 0.2 percentage points (this corresponds to a difference in pension of 0.25%). The treatment groups of the ERA increase of the 2000 pension reform are men born between October 1940 and September 1942 and women born born between October 1945 and September 1947. Therefore, my treatment groups are subject to the transition rules and are not strongly treated by the increase in the penalty. Especially, the differences between two adjacent quarters of birth are minimal. The 2000 pension reform also temporarily extended the maximum duration of unemployment benefits from 1 to 1.5 years for a subgroup of individuals. To qualify for the benefit extension individuals need at least 15 years of employment in the past 25 years and only certain birth cohorts in certain years were eligible. In 2000, only men born in 1940 and women born in 1945 were eligible. In 2001, men born in 1940-41 and women born in 1945-46 were eligible and in 2002 men born in 1940-1942 and women born in 1945-47 were eligible. The UI benefit extension ended in December 2002.

2.B.1 Results for the Pension Reform in 2000

2.B.2 Difference-in-Difference Estimation for Adjacent Birth Quarters

An alternative to my approach in the main text is to only compare adjacent quarters of birth with a difference-in-difference approach. In this case the counterfactual is different. For each group I estimate the effect of increasing the ERA by two months starting at the control group's ERA. The potential advantage of this approach is that adjacent quarters of birth might be more comparable and I observe them at almost the same point in time at a given age. The drawback is that sample size becomes relatively small. I implement this comparison with the following regression

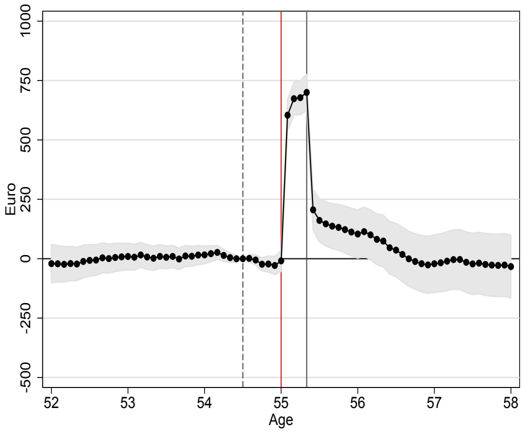
$$Y_{it} = \alpha + \sum_{k=ERA-6}^{ERA+6} \beta_k * Treat_i * I[age_{it} = k] + \sum_{k=ERA-6}^{ERA+6} \kappa_k * I[age_{it} = k] + Treat_i + \lambda_t + \varepsilon_{it}. \quad (2.47)$$

To make all changes directly comparable I normalize ages relative to the control groups ERA. Figures 2.29 to 2.32 plot the β_k estimates of the fiscal revenue effect as well as the mechanical effect of the ERA increase. We see the same patterns as in the analysis of the main text. The fiscal

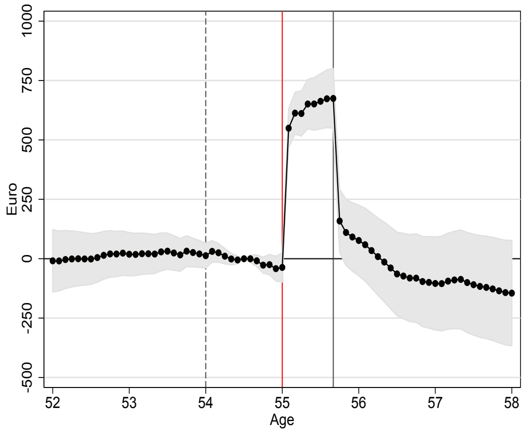
[31] That is, the pension of early claimaints can at most be 15 percent lower compared to their pension if they retired at NRA (with the same earnings history and number of insurance years).

Figure 2.18: DiD Estimates of Fiscal Revenue by Age: Women Reform 2000

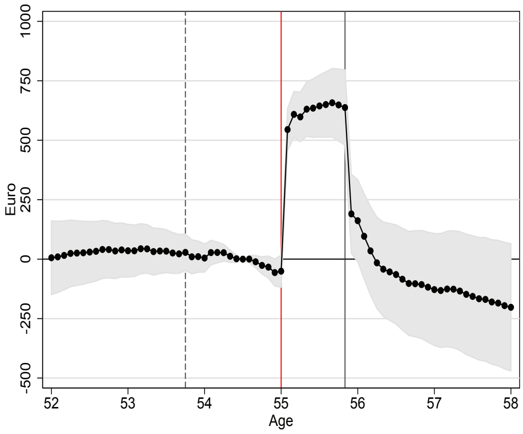
(a) ERA 55 + 4 months



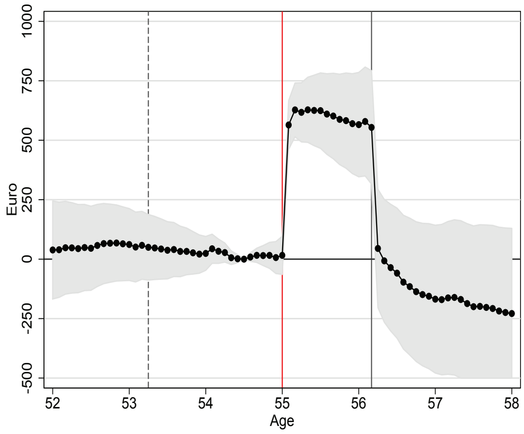
(b) ERA 55 + 8 months



(c) ERA 55 + 10 months



(d) ERA 56 + 2 months



(e) ERA 56 + 4 months

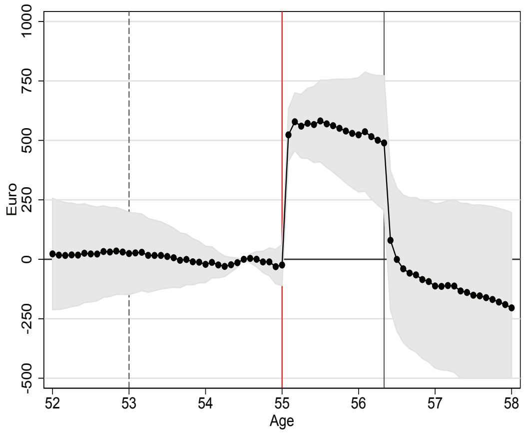
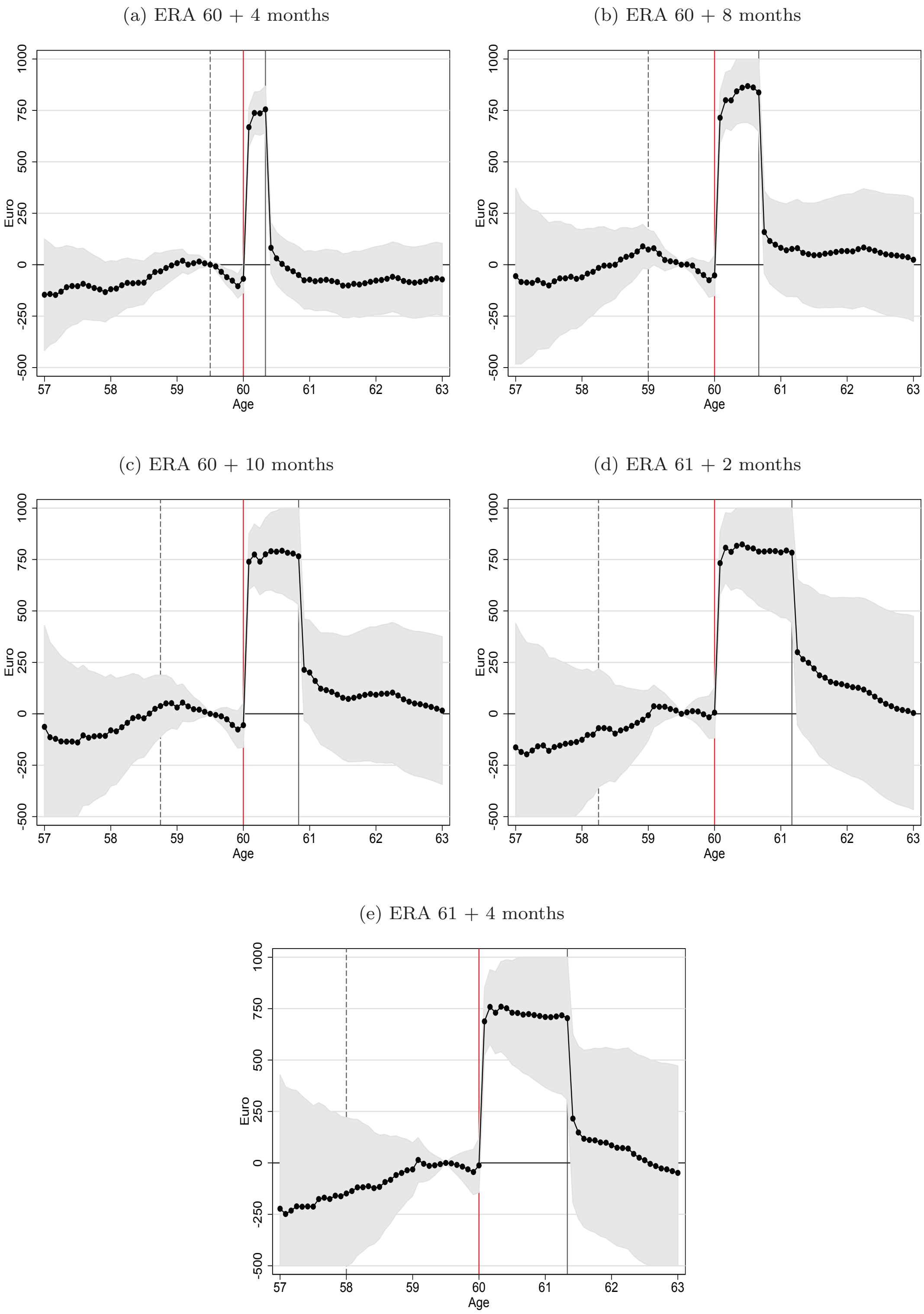


Figure 2.19: DiD Estimates of Fiscal Revenue by Age: Men Reform 2000



(a) ERA 60 + 4 months

(b) ERA 60 + 8 months

(c) ERA 60 + 10 months

(d) ERA 61 + 2 months

(e) ERA 61 + 4 months

Figure 2.20: Mechanical Effect for Women, Reform in 2000

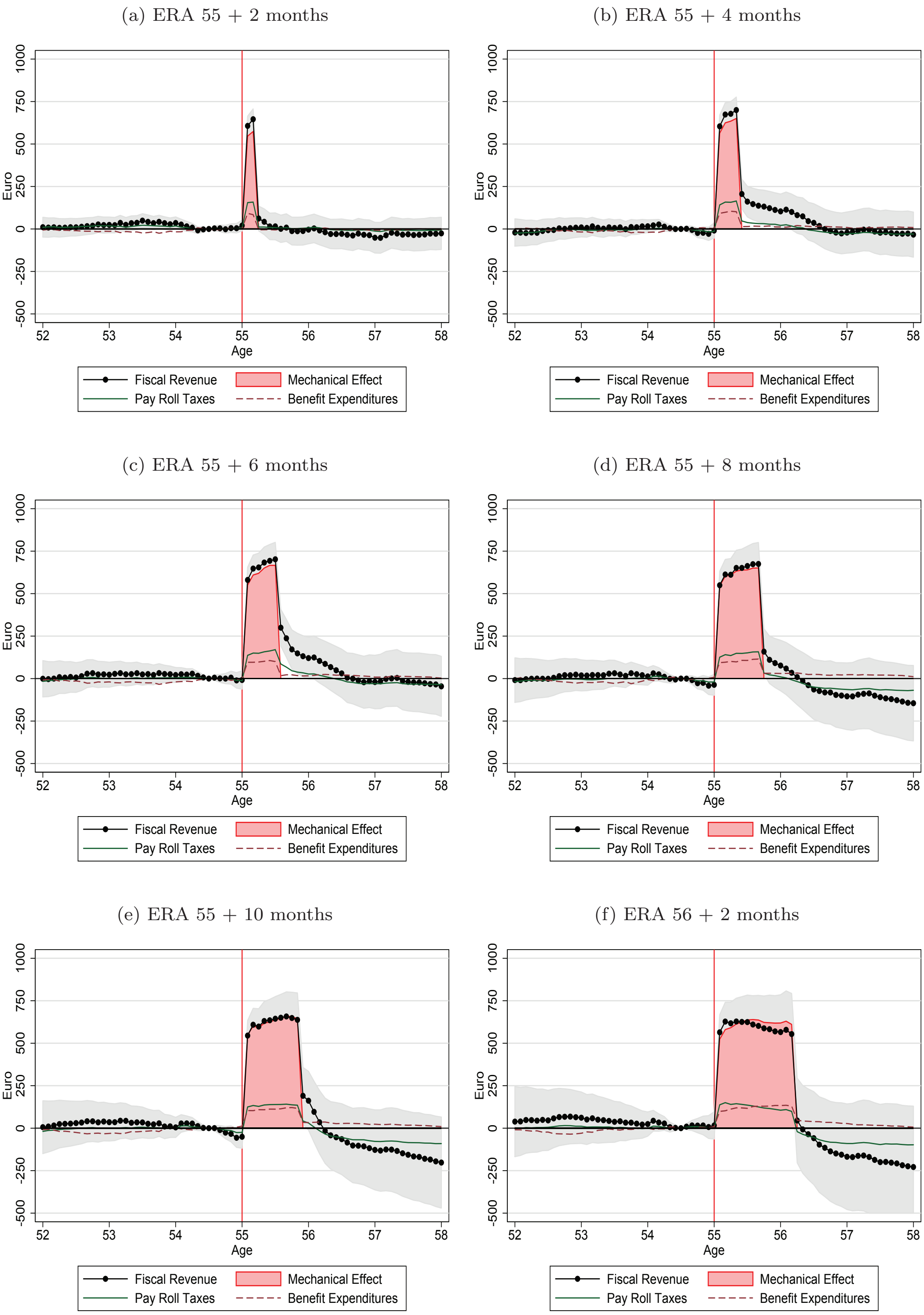
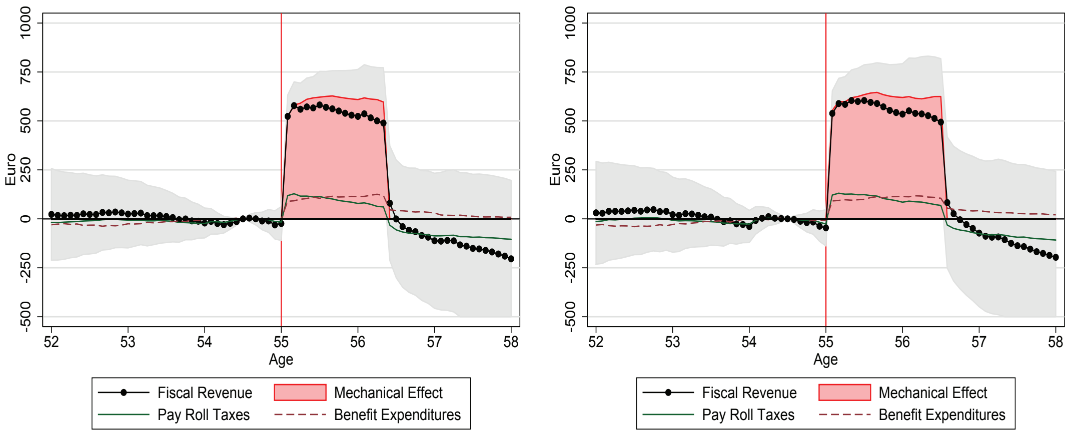


Figure 2.21: Mechanical Effect for Women, Reform in 2000

(a) ERA 56 + 4 months (b) ERA 56 + 6 months



revenue effect is predominantly driven by the mechanical effect and in some cases the multiplier is below one. Table presents 2.5 the detailed numbers. Due to the much lower sample size, the estimates become a bit more jumpy but the multipliers are still centered around one.

Table 2.5: Multipliers for the ERA Reform in 2000

ERA	Total Fiscal Effect	Mechanical	Behavioral	Multiplier (1+B/M)
Women				
ERA 55 + 2 months	1038	1120	-83	0.93
ERA 55 + 4 months	1227	1216	11	1.01
ERA 55 + 6 months	887	984	-97	0.90
ERA 55 + 8 months	972	823	148	1.18
ERA 55 + 10 months	1008	985	23	1.02
ERA 56	1029	892	138	1.15
ERA 56 + 2 months	934	885	50	1.06
ERA 56 + 4 months	1003	970	33	1.03
ERA 56 + 6 months	757	872	-115	0.87
Men				
ERA 60 + 2 months	1249	1448	-199	0.86
ERA 60 + 4 months	1528	1400	128	1.09
ERA 60 + 6 months	1381	1373	8	1.01
ERA 60 + 8 months	1103	1145	-42	0.96
ERA 60 + 10 months	1347	1213	134	1.11
ERA 61	1148	867	281	1.32
ERA 61 + 2 months	1052	1264	-212	0.83
ERA 61 + 4 months	1174	822	352	1.43
ERA 61 + 6 months	955	845	110	1.13

Figure 2.22: Mechanical Effect for Men, Reform in 2000

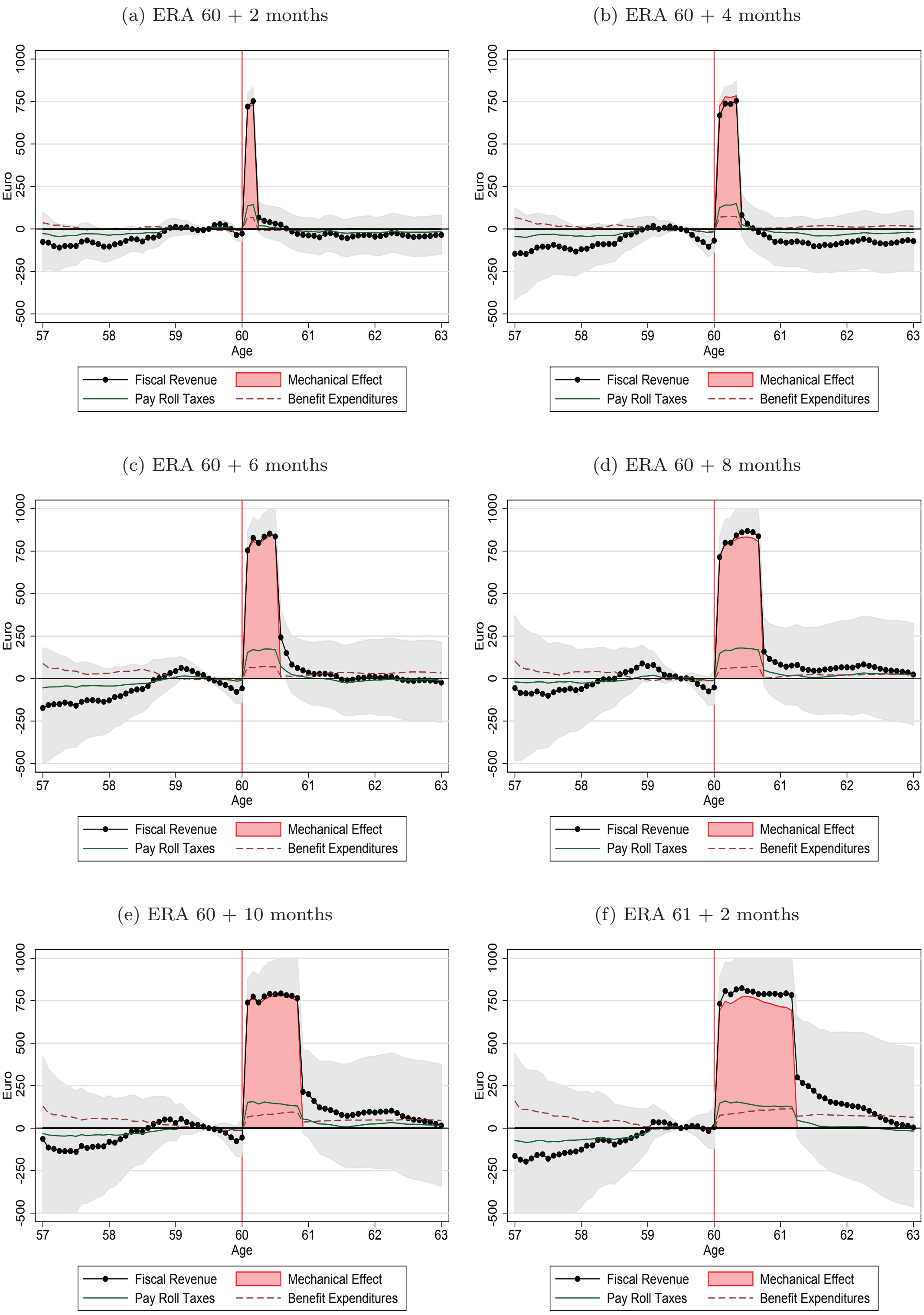
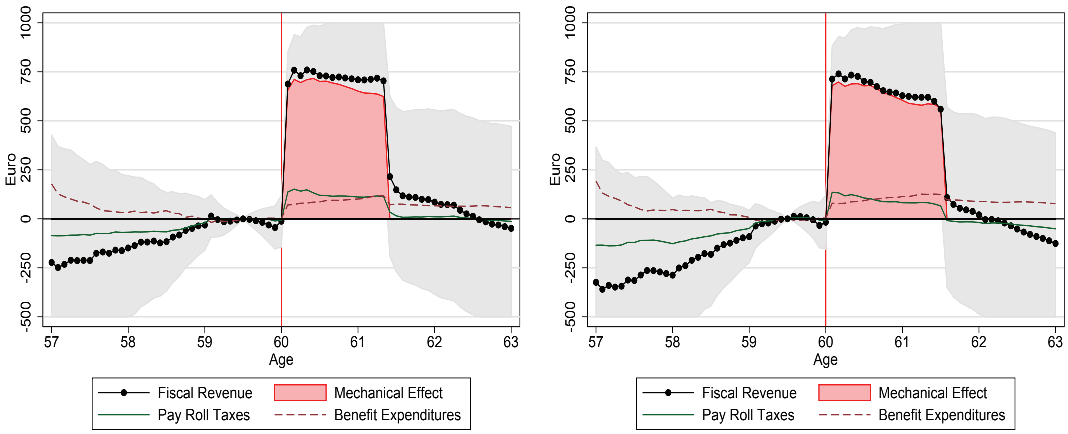


Figure 2.23: Mechanical Effect for Men, Reform in 2000

(a) ERA 61 + 4 months (b) ERA 61 + 6 months



2.C Early Retirement Age Reform 2003

The 2003 pension reform further increased the ERA from 56.5 to 60 for women and from 61.5 to 65 for men. However, the reform also changed the penalty for retiring early significantly and the replacement rate for a given number of insurance years. This makes it more difficult to separate the ERA from other changes. Nevertheless, the results are consistent with the results from the 2000 pension reform as multipliers are still around 1.

Other Policy Variation 2003 Pension Reform:

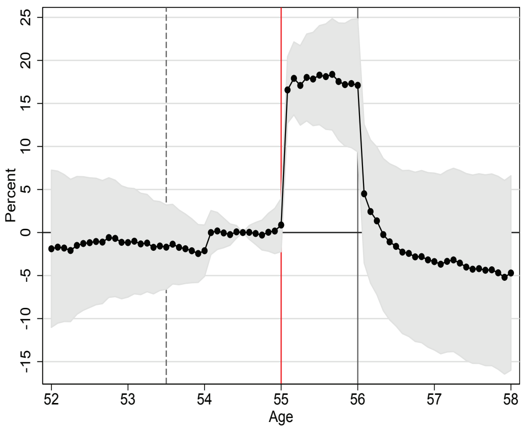
The 2003 pension reform reduces benefit generosity by reducing the pension coefficient for a given number of insurance years. Before the reform, each insurance year increased the pension coefficient by 2 percentage points, after the reform this is reduced to 1.78 percentage points. This change is also phased-in by claiming year: 1.96 pp in 2004, 1.92 pp in 2005, 1.88 pp in 2006, 1.84 pp in 2007, 1.80 pp in 2008, 1.78 pp since 2009. The penalty for claiming before the NRA is increased from 3 percentage points per year to 4.2 percentage points without transition rules. Furthermore, the assessment period changes from the best 15 to the best 40 years. This change is phased-in: Since 2004 the assessment period increases by one year each year until the assessment period is 40 years in 2028. The 2004 pension reform reintroduces the possibility of early retirement by creating the so-called corridor pension. Individuals with at least 37.5 insurance years. Until 2032 pension cuts resulting from the pension reform were capped at 10%, except for the losses due to the increase in the ERA. However, the 2004 pension reform sets this cap at 5% until 2024 and then gradually increases the cap to 10%.

2.C.1 Empirical Strategy for the Pension Reform in 2003

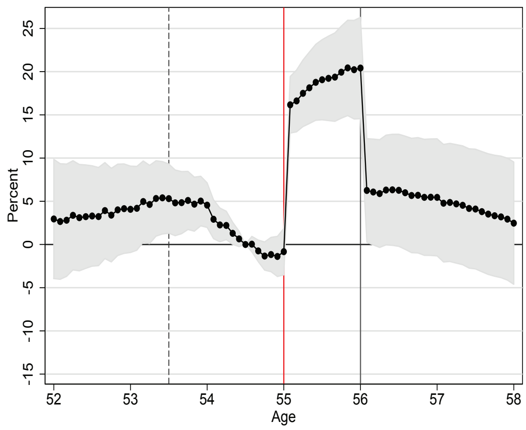
I exploit the variation in the ERA by quarter of birth in a cohort difference-in-difference specification analogous to the specification in the main text. I focus here on women because for men the ERA increase beyond age 62 was irrelevant for most individuals (see figure 2.34). Individuals with more than 37.5 insurance years can still retire at age 62 through the so called "corridor pension". Hence, most men were not affected by the ERA increase.

Figure 2.24: DiD Estimates for Labor Market Status by Age: Women ERA 56 months

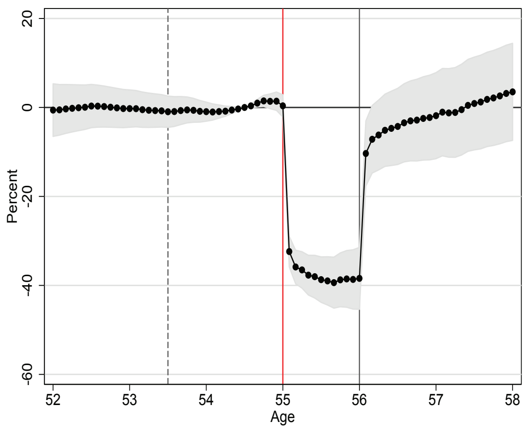
(a) Employment



(b) Unemployment



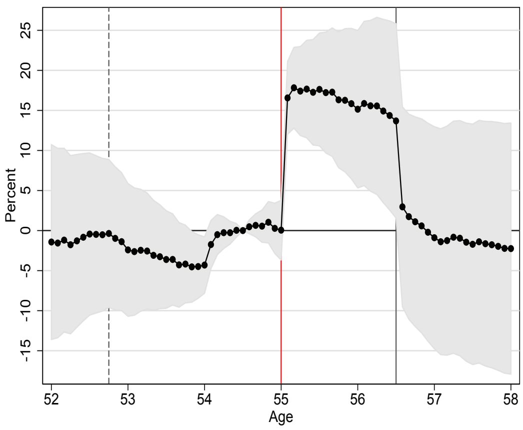
(c) Retirement (OA and DI)



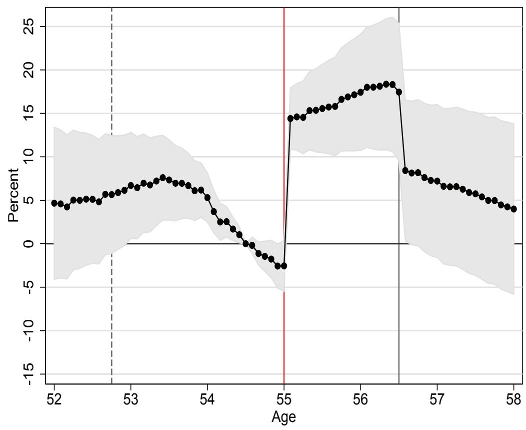
Notes: This figure shows the DiD estimates for employment, unemployment and retirement.

Figure 2.25: DiD Estimates for Labor Market Status by Age: Women ERA 56.5 months

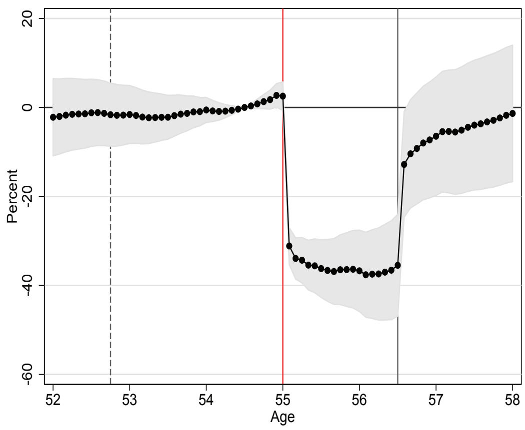
(a) Employment



(b) Unemployment



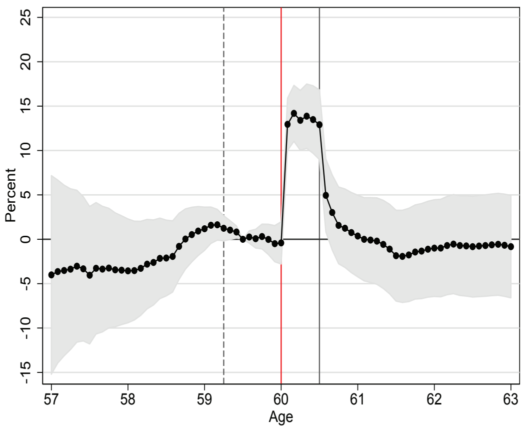
(c) Retirement (OA and DI)



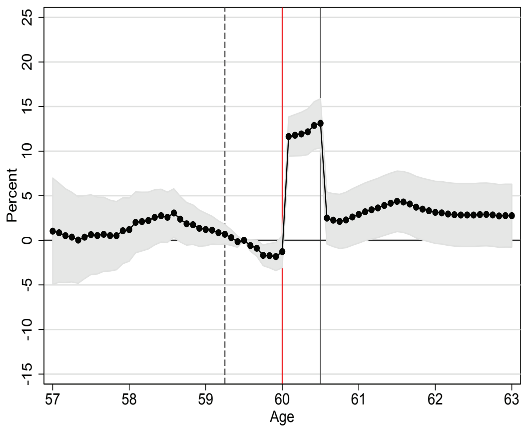
Notes: This figure shows the DiD estimates for employment, unemployment and retirement.

Figure 2.26: DiD Estimates for Labor Market Status by Age: Men ERA 60 + 6 months

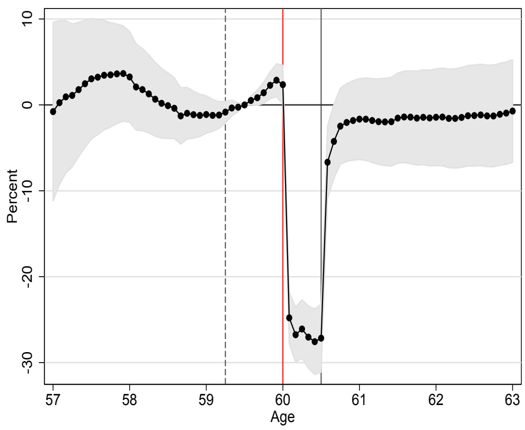
(a) Employment



(b) Unemployment



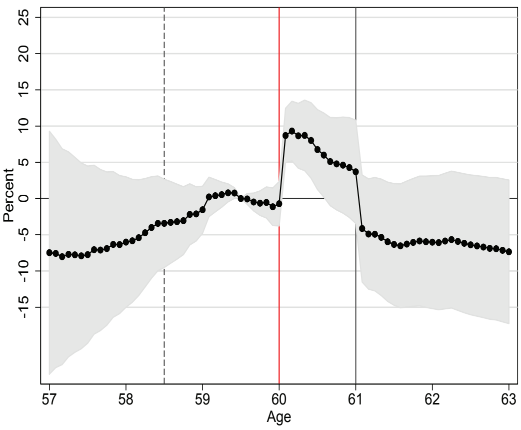
(c) Retirement (OA and DI)



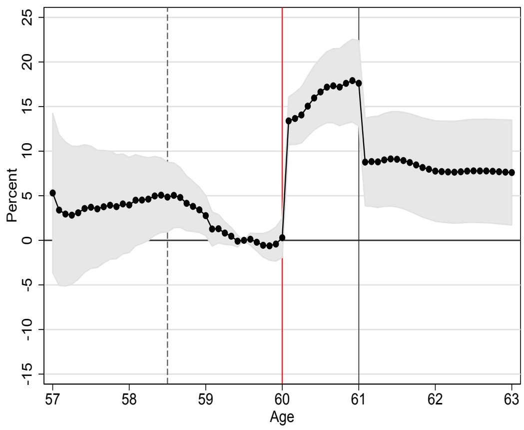
Notes: This figure shows the DiD estimates for employment, unemployment and retirement.

Figure 2.27: DiD Estimates for Labor Market Status by Age: Men ERA 61

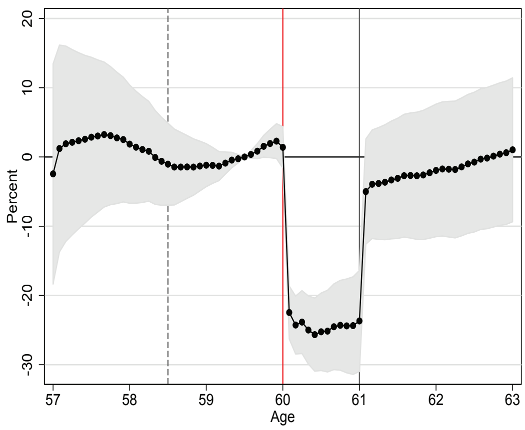
(a) Employment



(b) Unemployment



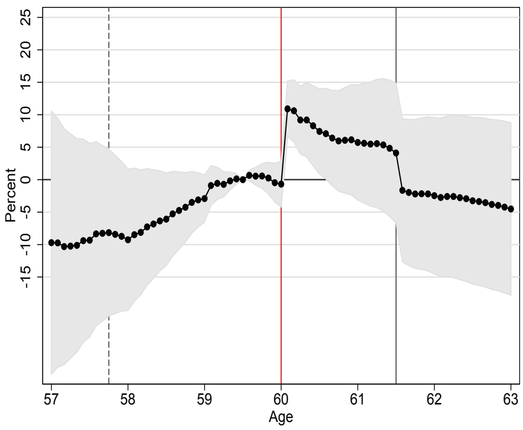
(c) Retirement (OA and DI)



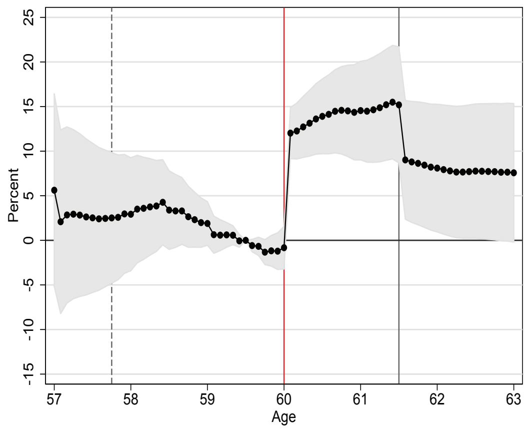
Notes: This figure shows the DiD estimates for employment, unemployment and retirement.

Figure 2.28: DiD Estimates for Labor Market Status by Age: Men ERA 61 + 6 months

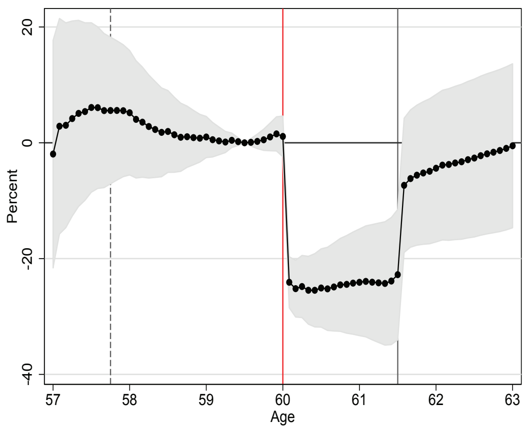
(a) Employment



(b) Unemployment



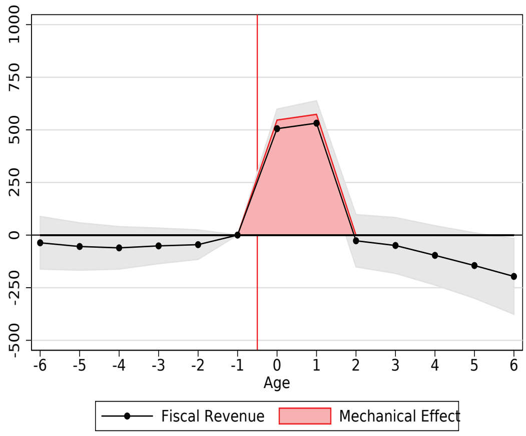
(c) Retirement (OA and DI)



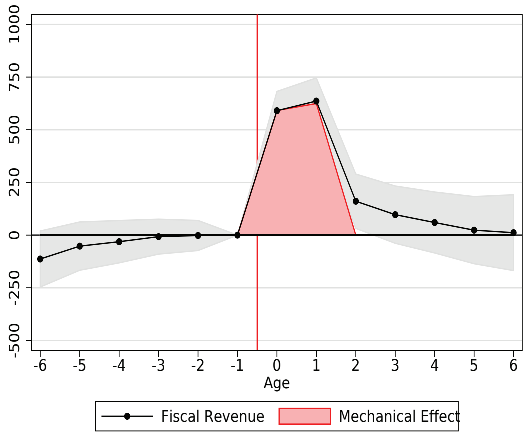
Notes: This figure shows the DiD estimates for employment, unemployment and retirement.

Figure 2.29: Mechanical Effect Women Reform 2000

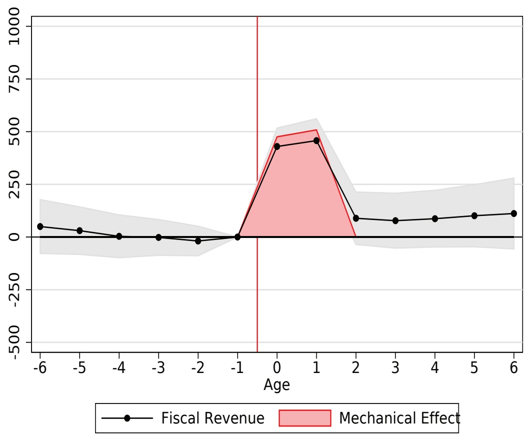
(a) ERA 55 + 2 months



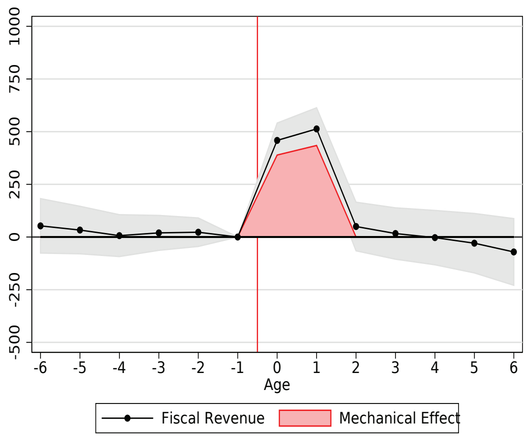
(b) ERA 55 + 4 months



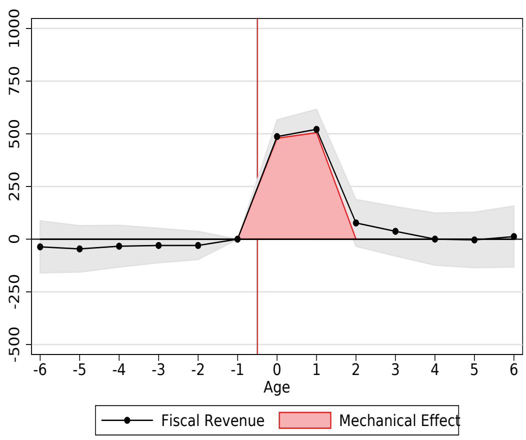
(c) ERA 55 + 6 months



(d) ERA 55 + 8 months



(e) ERA 55 + 10 months



(f) ERA 56 months

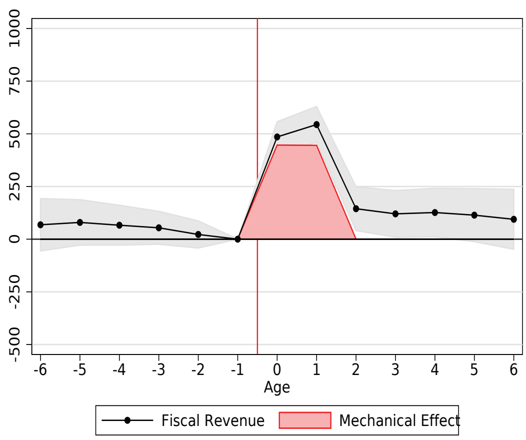
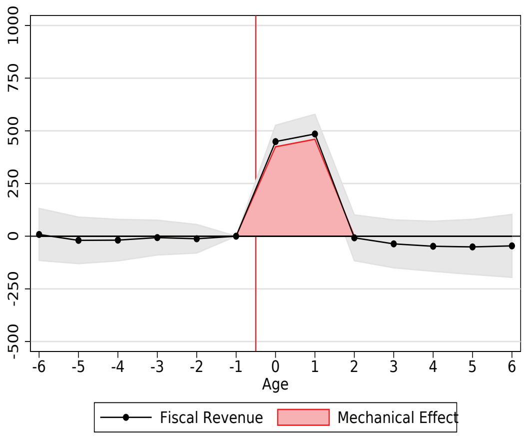
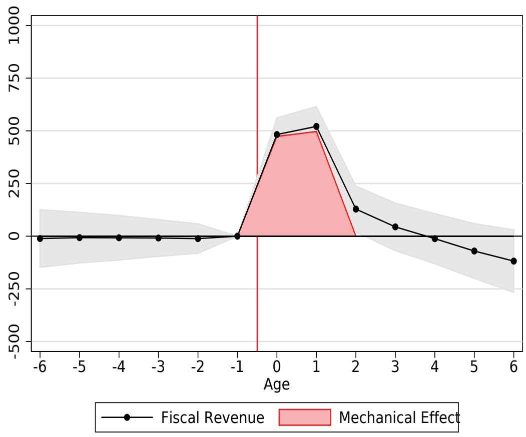


Figure 2.30: Mechanical Effect Women Reform 2000

(a) ERA 56 + 2 months



(b) ERA 56 + 4 months



(c) ERA 56 + 6 months

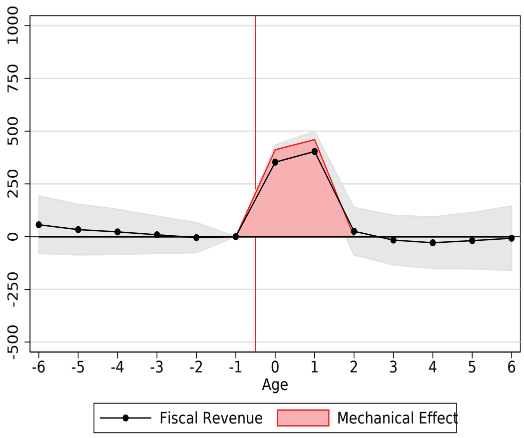


Figure 2.31: Mechanical Effect Men Reform 2000

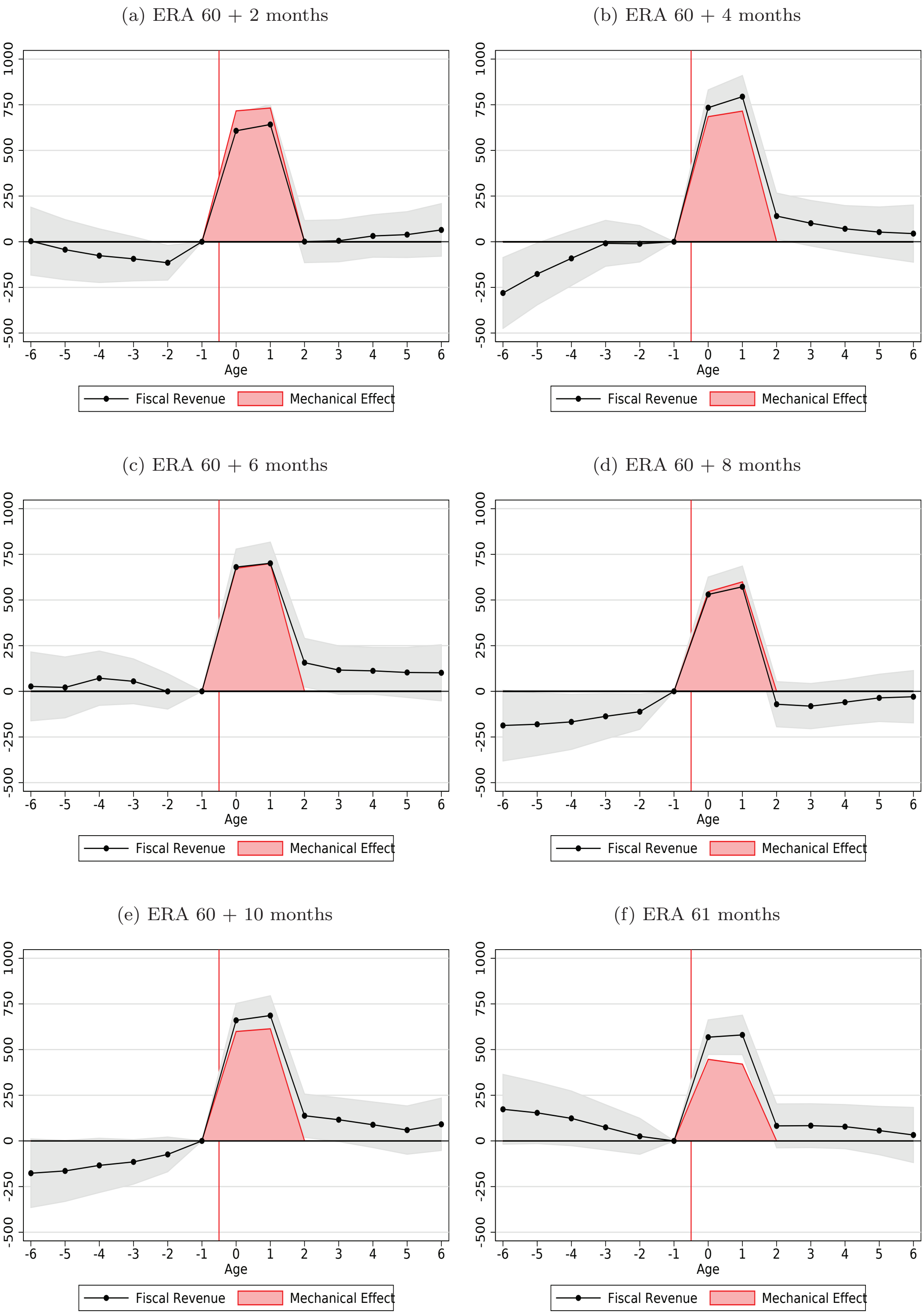
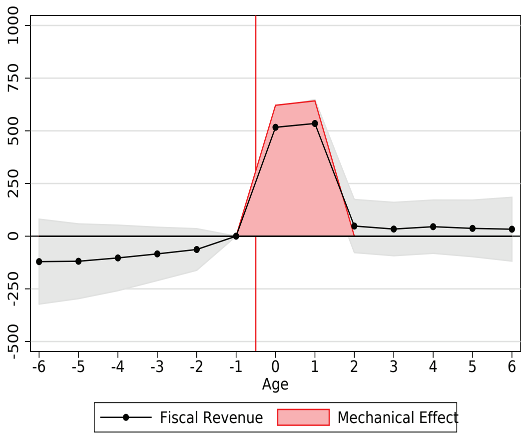
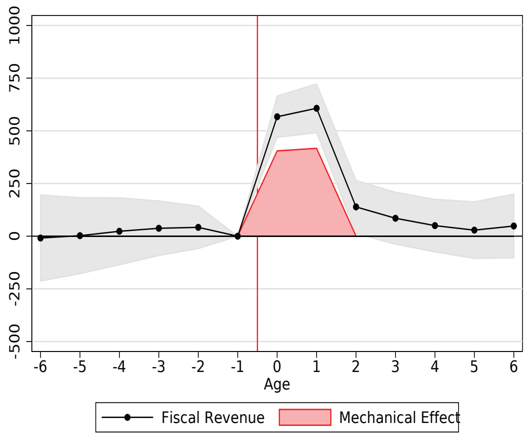


Figure 2.32: Mechanical Effect Men Reform 2000

(a) ERA 61 + 2 months



(b) ERA 61 + 4 months



(c) ERA 61 + 6 months

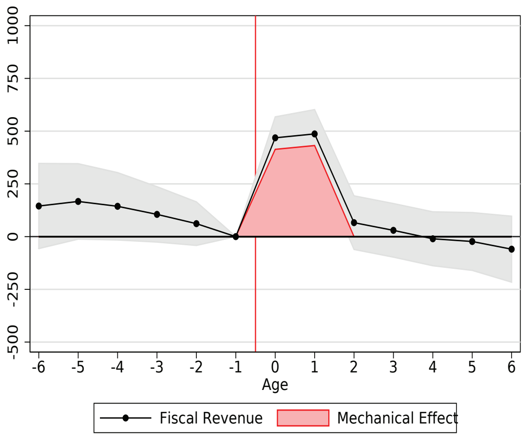
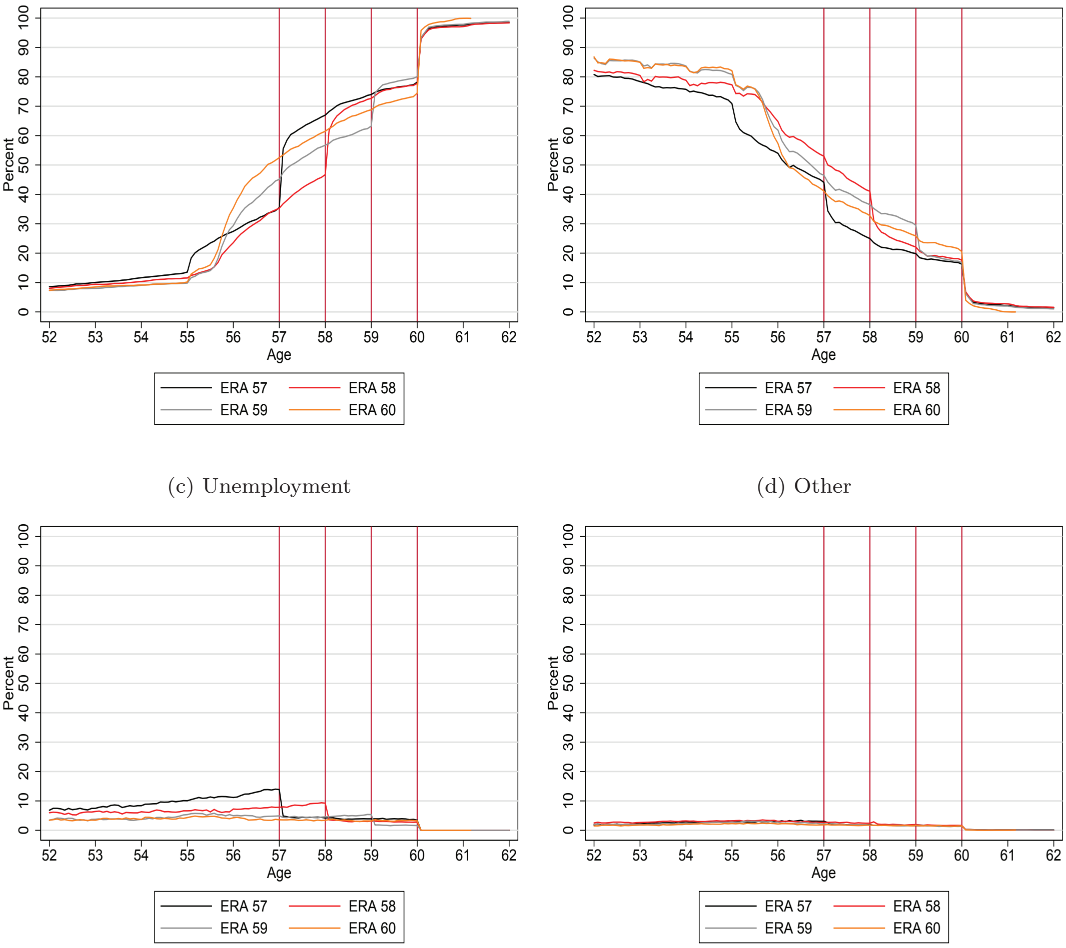


Figure 2.33: Reform 2003: Women Labor Market Status by Age

(a) Retirement (Disability and Old-Age) (b) Employment

(c) Unemployment (d) Other



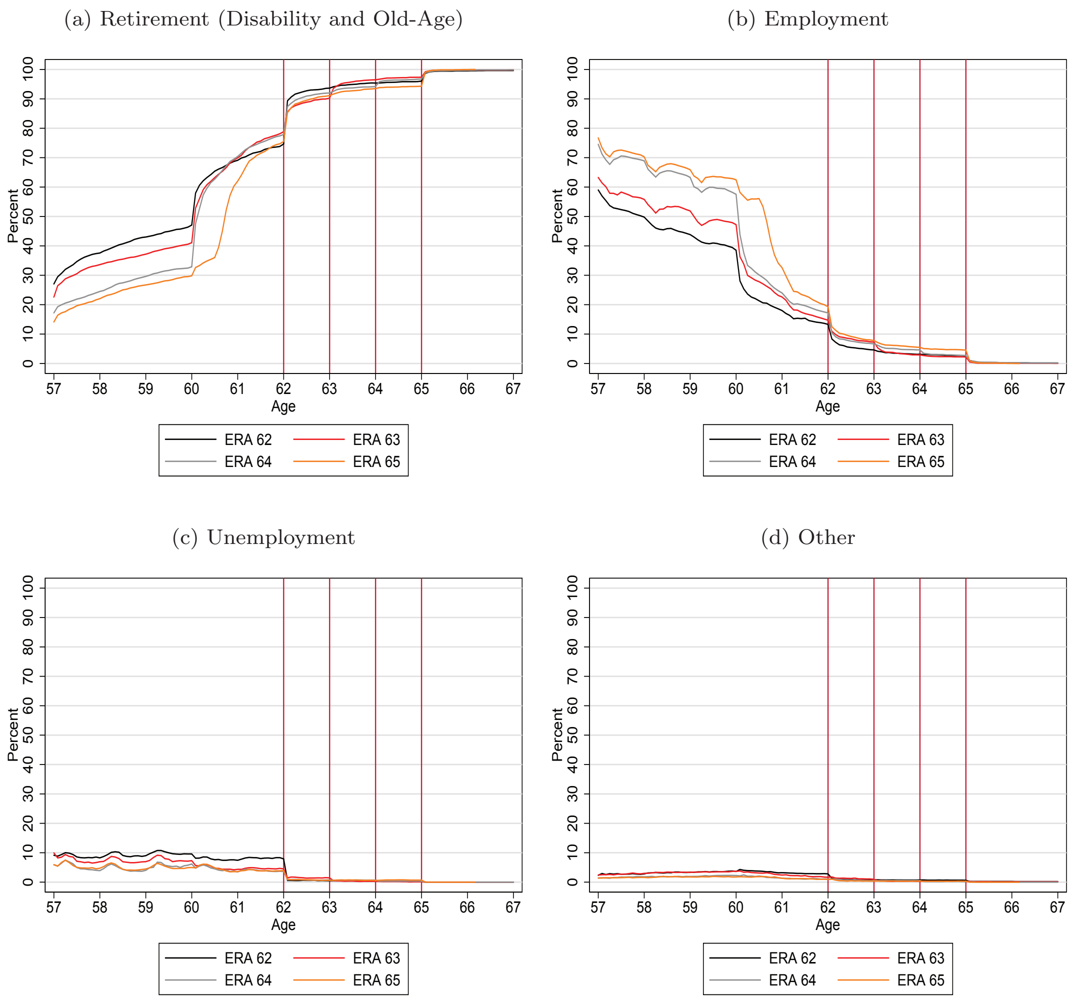
The control group for women is women born in 1948 Q2, with ERA 56 and 10 months. I take this control group since they are already affected by the change in the penalty and after this group the ERA increases by 1 month for each quarter of birth.

2.C.2 Descriptive Figures for the Pension Reform in 2003

2.C.3 Results Pension Reform 2003

For brevity, I focus here on fiscal outcomes and the multiplier. Figure 2.35 shows the fiscal revenue and mechanical effect for women for selected treatment groups. Table shows the multiplier for all groups for women. The main take-away from these tables is that the multiplier is still relatively small and around 1. However, the estimates of the multiplier can be a mix between increasing ERA, level shifts in generosity and changes in actuarial fairness (because the 2003 reform significantly changed other margins of the pension formula as discussed at the beginning).

Figure 2.34: Reform 2003: Men Labor Market Status by Age



(a) Retirement (Disability and Old-Age)

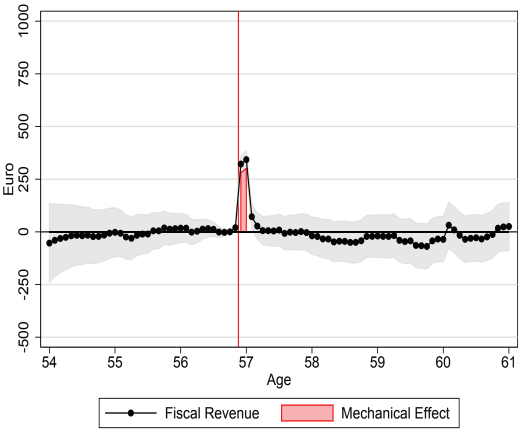
(b) Employment

(c) Unemployment

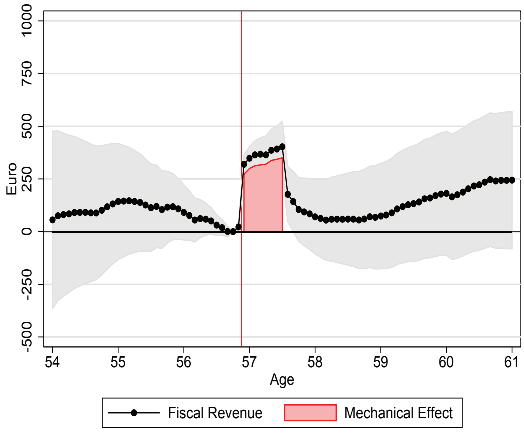
(d) Other

Figure 2.35: DiD Estimates Fiscal Revenue by Age: Men Reform 2003

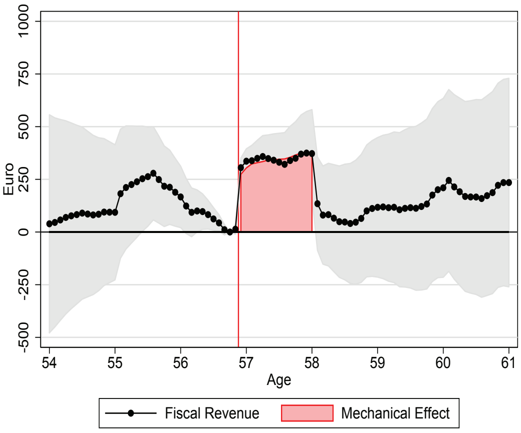
(a) ERA 57



(b) ERA 57 + 6 months

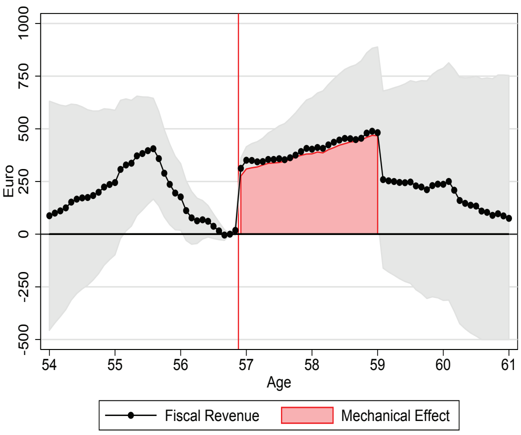


(c) ERA 58



(d) ERA 58 + 6 months

(e) ERA 59



(f) ERA 59 + 6 months

Table 2.6: Multiplier ERA Reform 2003

ERA	Fiscal Revenue Effect	Mechanical	Behavioral	Multiplier
Women				
ERA 56 + 11 months	303	260	43	1.16
ERA 57 months	665	582	83	1.14
ERA 57 + 1 months	1027	899	129	1.14
ERA 57 + 2 months	1328	1217	110	1.09
ERA 57 + 3 months	1719	1536	183	1.12
ERA 57 + 4 months	2083	1853	230	1.12
ERA 57 + 5 months	2364	2075	289	1.14
ERA 57 + 6 months	2945	2552	393	1.15
ERA 57 + 7 months	3291	2910	380	1.13
ERA 57 + 8 months	3566	3282	284	1.09
ERA 57 + 9 months	3752	3389	363	1.11
ERA 57 + 10 months	4373	3928	446	1.11
ERA 57 + 11 months	4725	4379	346	1.08
ERA 58 months	4835	4789	46	1.01
ERA 58 + 1 months	5299	5179	120	1.02
ERA 58 + 2 months	5944	5751	193	1.03
ERA 58 + 3 months	7058	6563	495	1.08
ERA 58 + 4 months	6526	6280	247	1.04
ERA 58 + 5 months	6908	6633	275	1.04
ERA 58 + 6 months	7897	7423	474	1.06
ERA 58 + 7 months	8894	8331	564	1.07
ERA 58 + 8 months	8936	8378	558	1.07
ERA 58 + 9 months	9378	8841	537	1.06
ERA 58 + 10 months	10305	9473	832	1.09
ERA 58 + 11 months	11545	10536	1009	1.10
ERA 59 months	10450	9928	522	1.05
ERA 59 + 1 months	11552	10949	603	1.06
ERA 59 + 2 months	12754	11911	843	1.07
ERA 59 + 3 months	13514	12453	1061	1.09
ERA 59 + 4 months	7386	10533	-3147	0.70
ERA 59 + 5 months	7795	10602	-2807	0.74
ERA 59 + 6 months	7933	10506	-2573	0.76
ERA 59 + 7 months	5607	9514	-3907	0.59
ERA 59 + 8 months	4735	8671	-3936	0.55
ERA 59 + 9 months	4227	7626	-3399	0.55
ERA 59 + 10 months	6251	8470	-2218	0.74

2.D Pension Level Reform

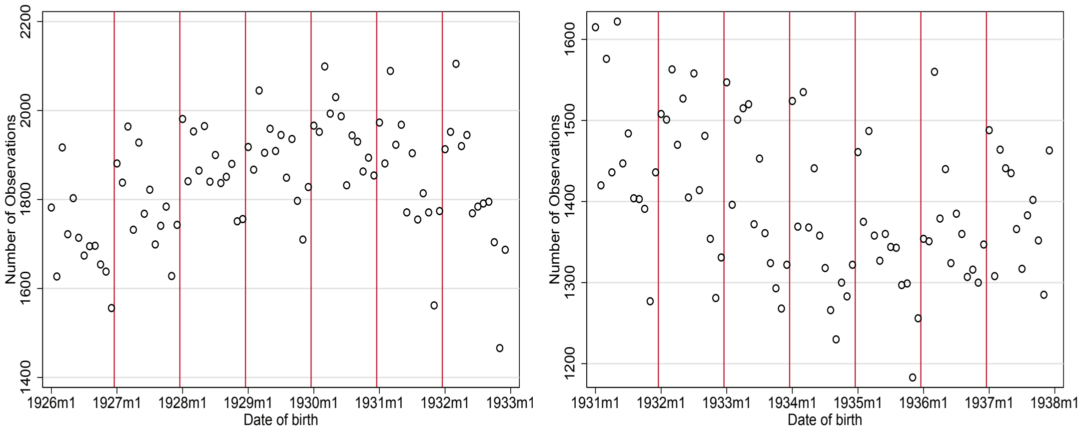
2.D.1 Balance Checks

Figure 2.36 shows that the number of observations around January is not balanced. This is potentially a problem. However, I do not find any effects for labor market outcomes or fiscal revenue before the reform. Moreover, figure 2.14 in the main text shows that the effects are driven by the treated group. I do not find effects for the placebo group that is unaffected by the reform.

This speaks for the validity of my RDD despite the unbalanced number of observations around the cut-off.

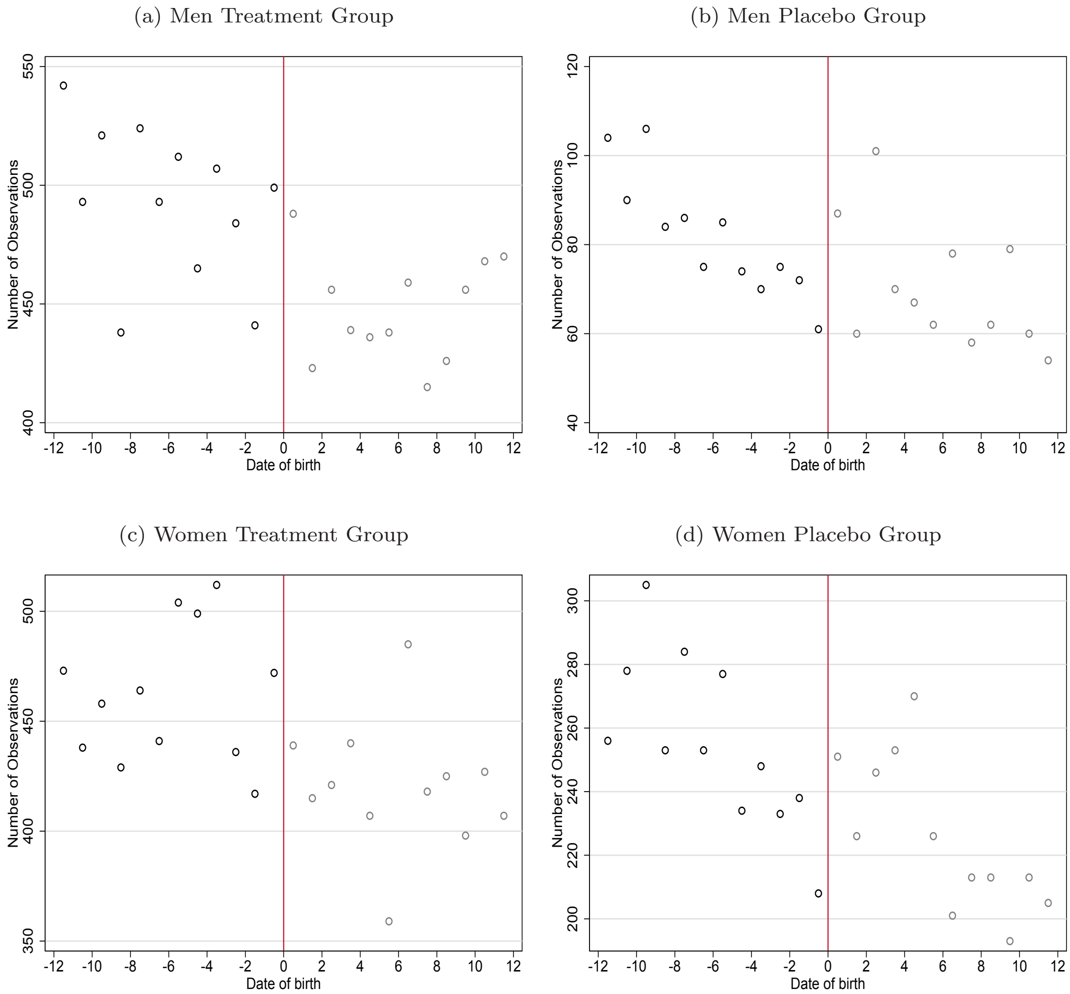
Figure 2.36: Number of Observations by Date of Birth

(a) Men (b) Women



Notes: This figure shows the number of observations by date of birth. Around January the number of observations is not balanced. However, this is unlikely to be driven by manipulation as a response to the reform.

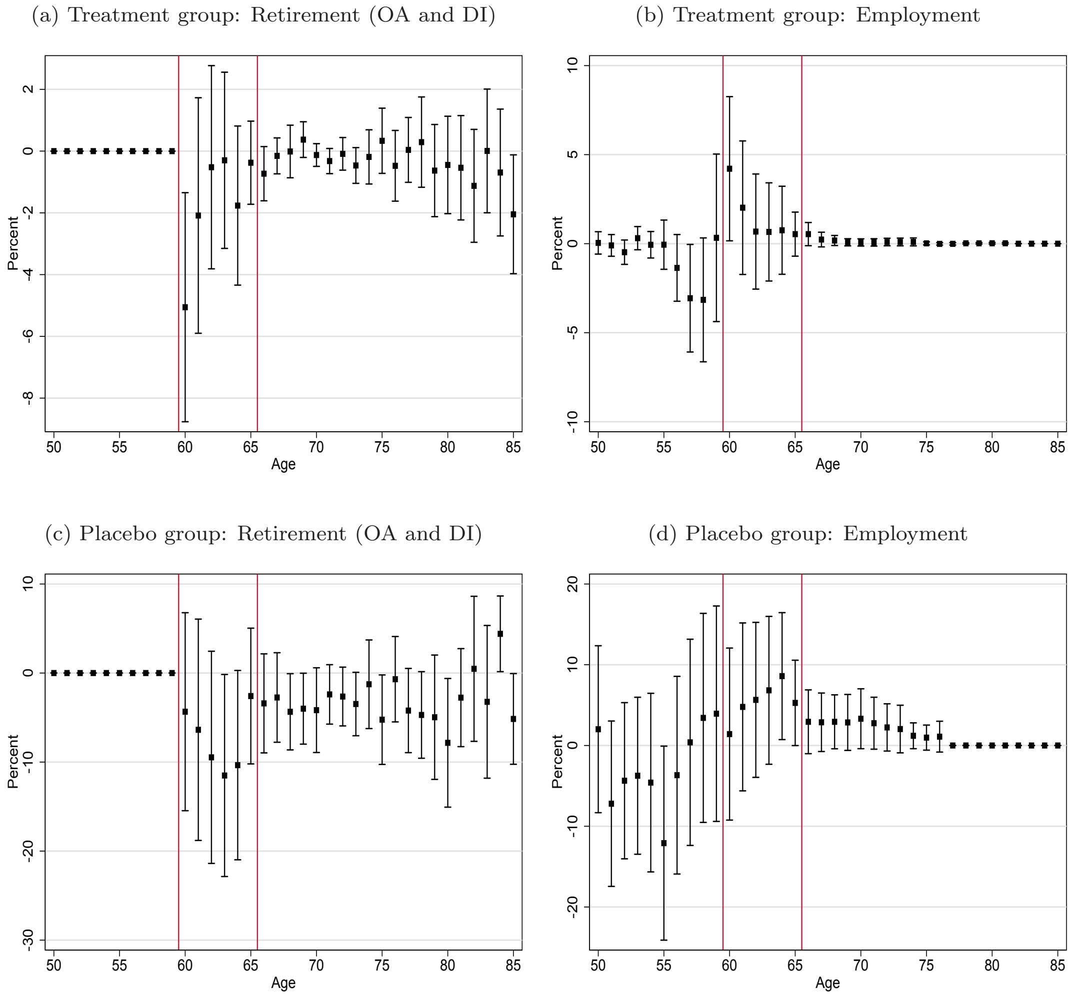
Figure 2.37: Number of Observations by Date of Birth



Notes: This figure shows the number of observations by date of birth for the treatment and placebo groups. The cutoff is at 1.1.1928 for men and 1.1.1933 for women.

2.D.2 Additional Figures and Tables for Men

Figure 2.38: RD Estimates by Age: Labor Supply Men Treatment and Placebo



(a) Treatment group: Retirement (OA and DI)

(b) Treatment group: Employment

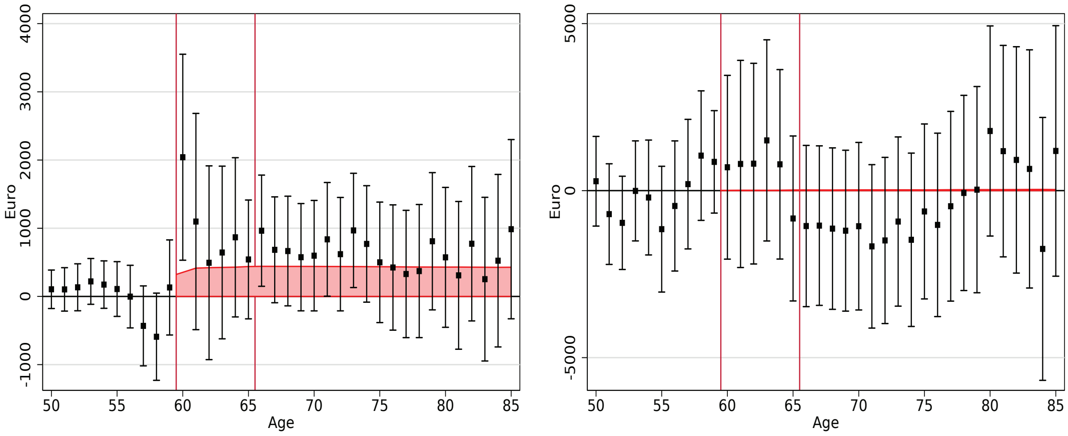
(c) Placebo group: Retirement (OA and DI)

(d) Placebo group: Employment

Notes: This figure plots the RD estimates at each age between 50 and 85 based on local linear regressions with a bandwith of 8 months.

Figure 2.39: RD Estimates by Age: Fiscal Effect Men Treatment and Placebo

(a) Men Treatment Group (b) Men Placebo Group



Notes: This figure plots the RD estimates for fiscal revenue by age (black squares with 95 CI, based on local linear regressions with bandwidth 8 months). The red area indicates the mechanical fiscal effect of the reform.

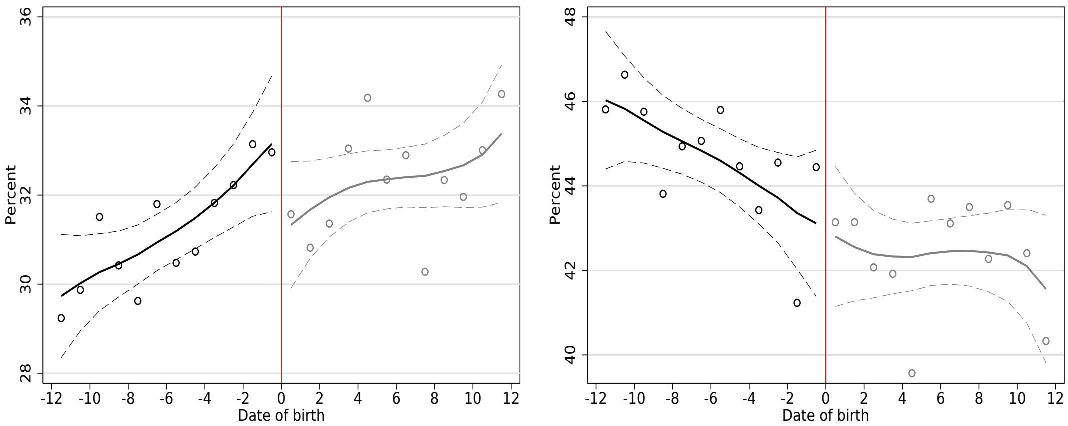
Table 2.7: Multiplier Benefit Generosity by Discount Rate and Bandwidth

Discount rate:	r=0%	r=2%	r=5%	r=7%
Multiplier Men				
bandwith = 2	2.34	2.62	3.08	3.39
bandwith = 4	1.61	1.75	1.96	2.10
bandwith = 6	1.48	1.59	1.76	1.88
bandwith = 8	1.39	1.48	1.62	1.72
bandwith = 10	1.30	1.37	1.49	1.57
Multiplier Women				
bandwith = 2	1.92	2.15	2.52	2.77
bandwith = 4	1.78	1.98	2.31	2.55
bandwith = 6	1.94	2.19	2.59	2.88
bandwith = 8	1.66	1.84	2.12	2.32
bandwith = 10	1.45	1.56	1.76	1.89

2.D.3 RDD Figures Women

Figure 2.40: Retirement and Employment at Age 55: Women

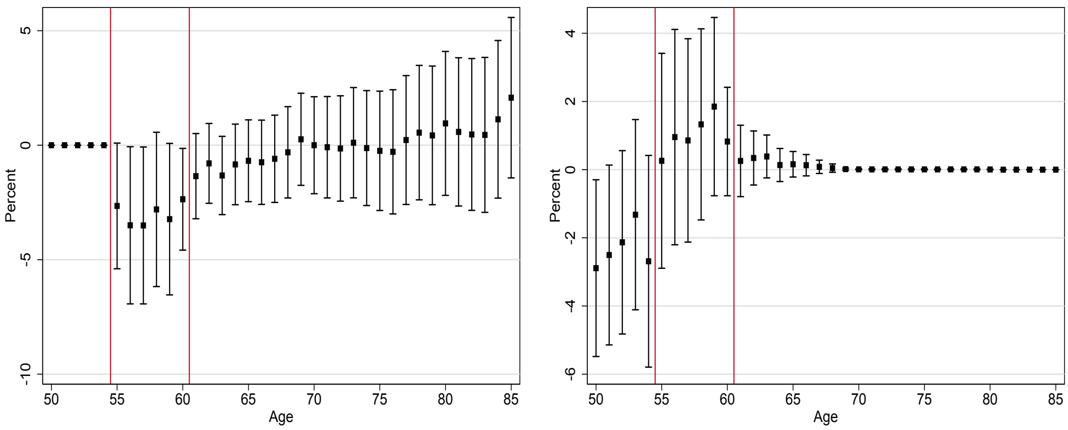
(a) Retirement (OA and DI) (b) Employment



Notes: This figure shows the average retirement and employment rates at age 60. The fitted lines are local linear polynomials with a bandwidth of 8 months.

Figure 2.41: RD Estimates by Age: Labor Supply Women

(a) Retirement (OA and DI) (b) Employment

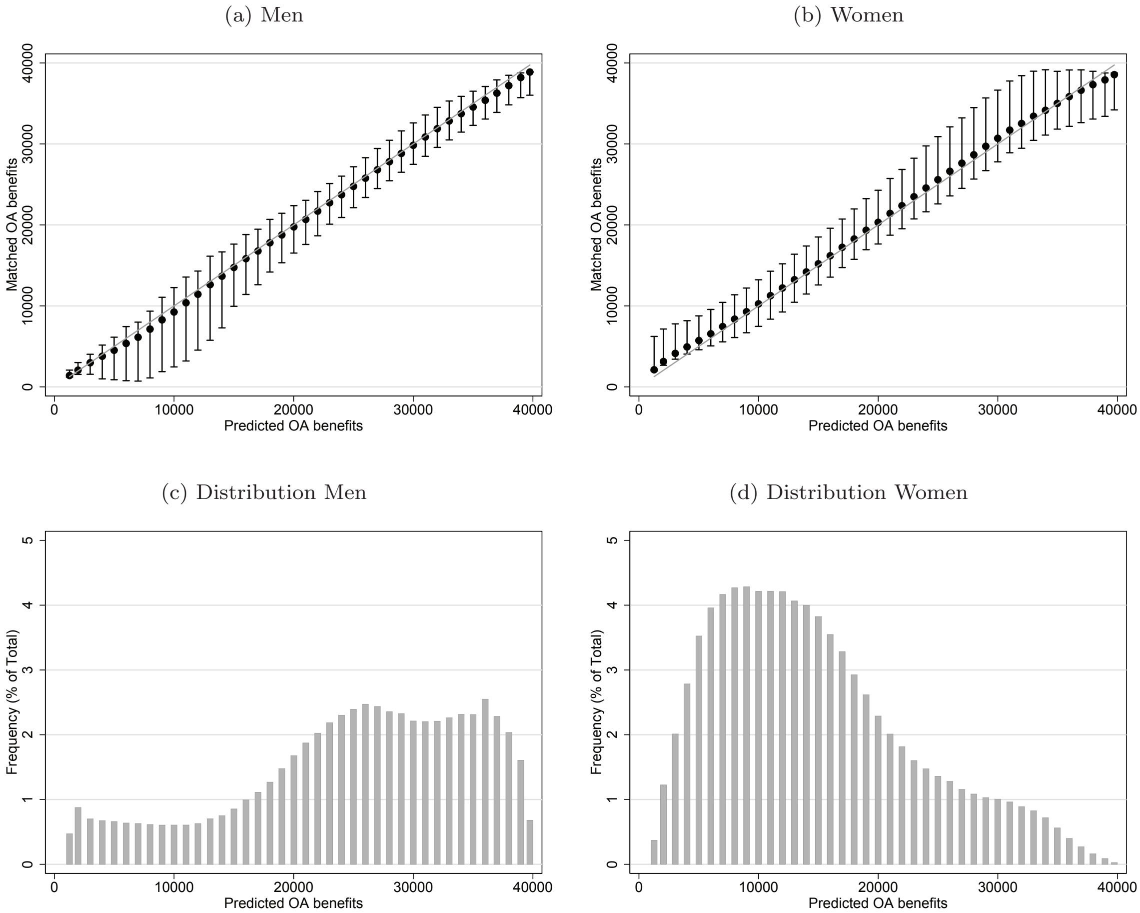


Notes: This figure plots the RD estimates at each age between 50 and 85 based on local linear regressions with a bandwith of 8 months.

2.E Data: Pension Benefit Calculation

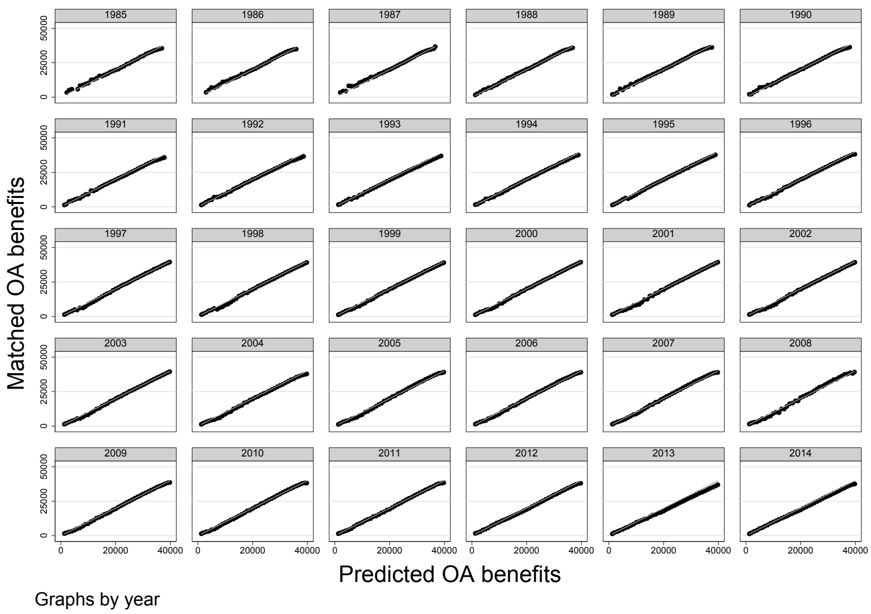
The ASSD provide all information necessary to compute individual old-age and disability pensions. I validate my pension calculations by comparing my predicted old-age pensions with actual old-age pensions for the subsample of retirees who received benefits in 2001 or who retired after 2001, using matched data obtained from the Austrian Social Security Administration. Figure 2.42 plots mean matched old-age pensions against mean predicted old-age pensions (in 1000-Euro bins), pooling all years from 1985 to 2014. To get a sense of the distribution of predicted benefits I plot the 95th percentile (upper bar) and the 5th percentile (the lower bar), i.e. 90% of all observations lie between the two bars. Figures 2.43 and 2.44 plot this for each year separately. Figure 2.45 shows the same exercise for disability pensions. In all years, actual pensions track predicted pensions very closely.

Figure 2.42: Imputed and Matched Old-Age Pensions (Years 1985-2014)



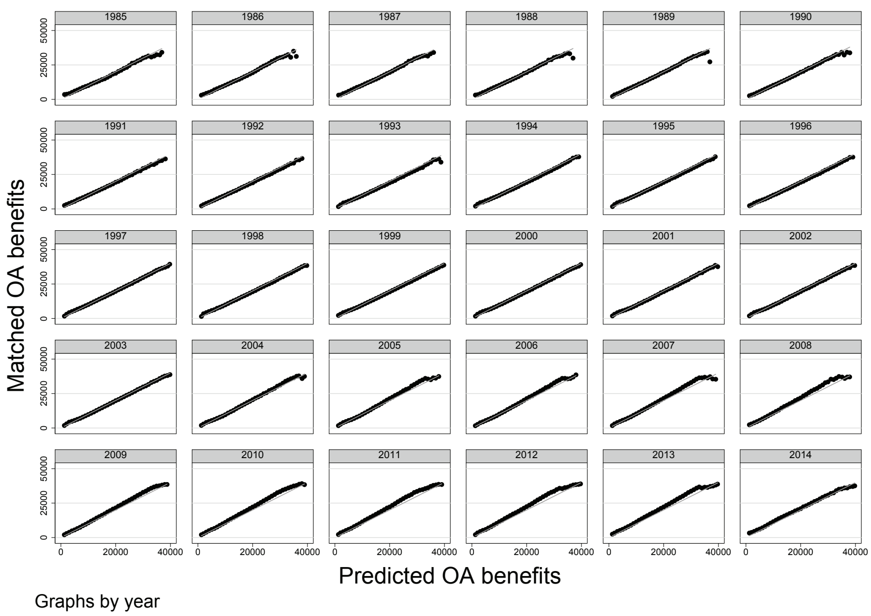
Notes: This figure plots mean matched old-age pensions against mean predicted old-age pensions (in 1000-Euro bins), pooling all years from 1985 to 2014. The bars represent the 95th percentile (upper bar) and the 5th percentile (the lower bar), the dot represents the mean. Panels (c) and (d) show the relative frequency of pension levels for men and women in this subsample.

Figure 2.43: Imputed and Matched Old-Age Pensions by Year: Men



Notes: This figure plots mean matched old-age pensions against mean predicted old-age pensions (in 1000-Euro bins) for each year separately.

Figure 2.44: Imputed and Matched Old-Age Pensions by Year: Women

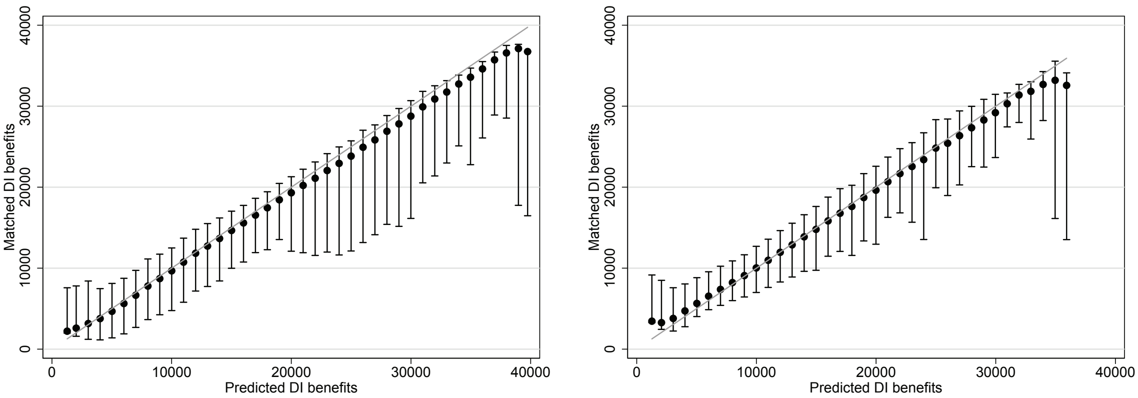


Notes: This figure plots mean matched old-age pensions against mean predicted old-age pensions (in 1000-Euro bins) for each year separately.

Figure 2.45: Imputed and Matched Disability Pensions (Years 1985-2014)

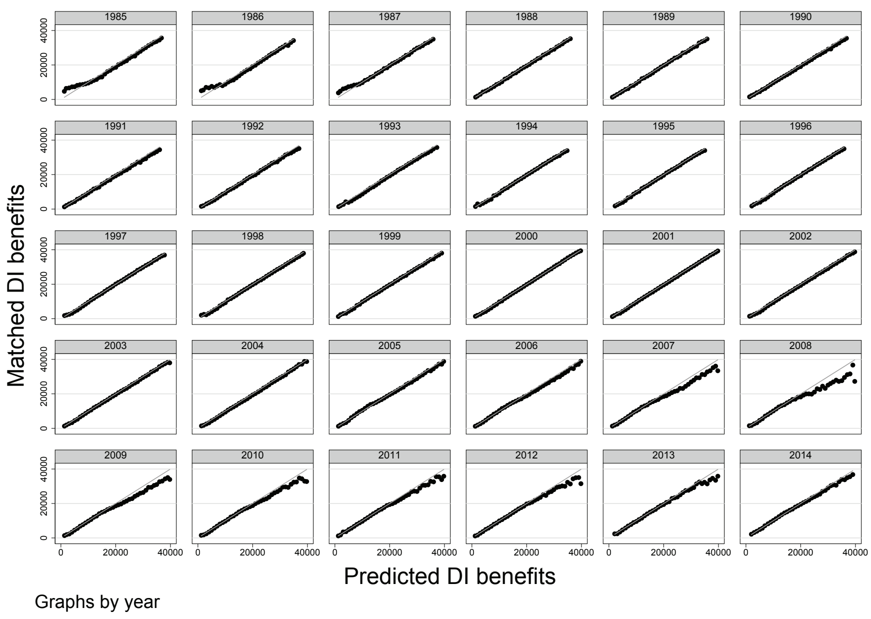
(a) Men

(b) Women



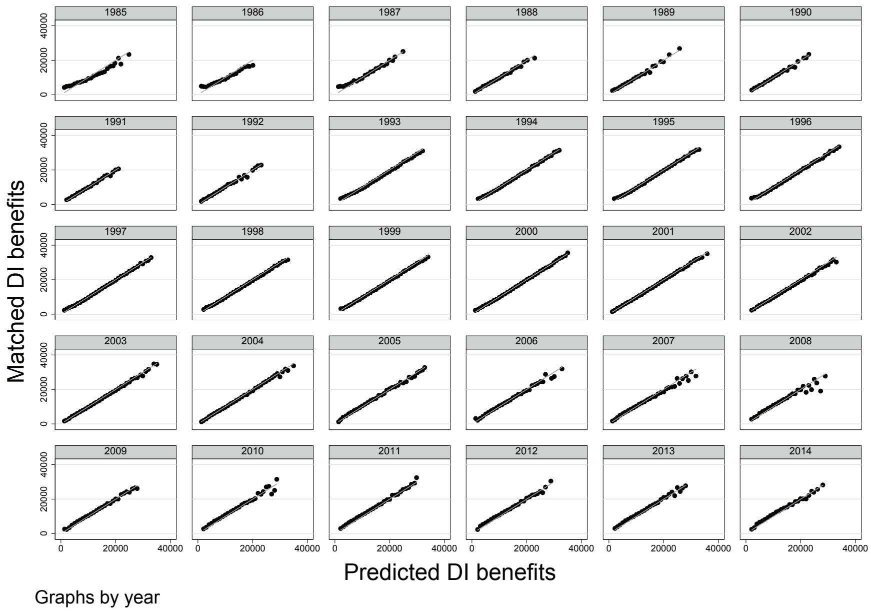
Notes: This figure plots mean matched disability pensions against mean predicted disability pensions (in 1000-Euro bins), pooling all years from 1985 to 2014. The bars represent the 95th percentile (upper bar) and the 5th percentile (the lower bar), the dot represents the mean.

Figure 2.46: Imputed and Matched Disability Pensions by Year: Men



Notes: This figure plots mean matched disability pensions against mean predicted old-age pensions (in 1000-Euro bins) for each year separately.

Figure 2.47: Imputed and Matched Disability Pensions by Year: Women



Notes: This figure plots mean matched disability pensions against mean predicted old-age pensions (in 1000-Euro bins) for each year separately.

Chapter 3

Designing Disability Insurance Reforms: Tightening Eligibility Rules or Reducing Benefits?

joint with Stefan Staubli and Josef Zweimüller

Abstract. This paper provides a framework to evaluate disability insurance (DI) reforms, capturing insurance value and fiscal costs of changes in the two main DI policy parameters: (i) the strictness of DI eligiblity rules and (ii) the level of DI benefits. We show that fiscal multipliers, the total fiscal cost relative to the mechanical fiscal effect of a reform, are crucial to evaluate the effectiveness of these DI policy parameters. Empirically, we exploit exogenous variation in strictness of eligibility rules and benefit levels arising from several DI reforms in Austria. We find that stricter eligibility rules significantly reduce the DI inflow through both a mechanical effect (fewer applicants qualify for benefits under stricter rules), and a behavioral effect (less workers apply for benefits). Similarly, a decrease in DI benefits is associated with a significant reduction in the DI inflow. Stricter eligibility rules create fiscal multipliers of 2-2.5 and reducing benefit generosity has fiscal multipliers of 1.3-1.4. Hence, by imposing stricter DI eligibility rules the policy maker can induce larger behavioral changes and generate greater cost reductions compared to reducing DI benefit levels making DI eligibility rules the more effective policy parameter.

3.1 Introduction

The share of individuals receiving Disability Insurance (DI) has increased significantly during the last two decades in many countries. For example, in the United States 2.6 percent of individuals in the age group of 20 to 64 were receiving DI benefits in 1992, but by 2012 this fraction had risen to 5.3 percent. This growth has generated substantial interest by policy makers and economists in measures that reduce DI program caseloads and expenditures.

Two potential ways to slow program inflow are to tighten DI eligibility rules and to reduce DI benefit levels. Yet, little is known about the welfare effects of these measures. This paper helps to fill this gap by providing sufficient statistics formulas for welfare analysis that capture the insurance value and incentive costs of changes in eligibility criteria and benefit levels. These formulas are functions of parameters that can be estimated using design-based empirical methods.[1] Our theoretical analysis shows that fiscal multipliers are crucial to evaluate the effectiveness of DI policy parameters. A fiscal multiplier measures the total fiscal cost relative to the mechanical fiscal effect of a reform. Estimating fiscal multipliers has recently become popular to evaluate policy programs (Hendren and Sprung-Keyser, 2019; Lee et al., 2019).[2] This is the first paper to show the relevance of fiscal multipliers in the DI context. DI programs differ to other social insurance programs because eligibility is based on the inability to work. The inherent problem of the DI assessment process is that the true disability is the agent's private information. For this reason, a DI applicant has to undergo a disability assessment process, which delivers an estimate of her disability to the government and determines her eligibility to receive benefits. Changes in disability eligibility criteria are therefore very different in nature than changes in benefit generosity. Stricter eligibility rules reduce access to DI benefits for some individuals and do not affect individuals who still qualify for DI under the stricter rules. We provide a unifying framework that allows to study the welfare effects of changing DI eligibility rules and DI benefits. Moreover, we show how these two instruments can be optimally combined (optimal policy mix). Empirically estimating the fiscal multiplier of stricter DI eligibility is not straightforward. Stricter eligibility rules lead mechanically to lower DI award rates but at the same time change application behavior. To directly estimate the mechanical effect of stricter eligibility rules one would need to know the hypothetical change in the award rates at the individual level. This is a counterfactual we cannot observe.[3] An empirical innovation of this paper is to develop an approach to estimate the mechanical fiscal effect and the fiscal multiplier of stricter DI eligibility criteria.

We estimate fiscal multipliers of stricter DI eligibility rules and lower DI benefits by exploiting quasi-experimental variation of DI policies in Austria. Studying the Austrian case has several advantages. *First*, we can use the Austrian Social Security Administration database (ASSD) which contains the complete labor market and earnings histories of all private-sector workers in Austria dating back to 1972. Additionally, we have detailed information on the various stages of the application process for all DI applications since 2004. *Second*, we are able to exploit exogenous variation in DI eligibility criteria and benefits which is generated by several policy reforms. The combination of detailed labor market and application data and quasi-experimental policy variation gives us the unique opportunity to study the impact of stricter screening and changes in benefit levels on DI inflow, DI applications, labor force outcomes and fiscal costs. *Third*, certain features of the Austrian DI- and social protection systems are similar to other countries. In particular, as described in more detail below, the Austrian reforms we are exploiting are comparable to reforms that have been proposed in the United States.

Our identification strategy to estimate the effects of stricter disability screening exploits variation in DI eligibility criteria that is generated by a policy reform. Prior to 2013 DI eligibility

[1] Recent applications of the sufficient statistic approach for optimal UI design include Shimer and Werning (2007), Chetty (2008), Kroft (2008), Landais et al. (2010), Kroft and Notowidigdo (2011), Schmieder et al. (2012), and Landais (2012). See the article by Chetty and Finkelstein (2013) for a detailed discussion of this literature.

[2] These papers estimate the "fiscal externality" of reforms, which equals the fiscal multiplier minus one.

[3] Estimating the mechanical fiscal effect of a benefit level reform is straightforward as we can directly calculate by how much individual benefits change due to the reform. It is (usually) not possible to directly calculate the effect of a change in DI eligibility rules on DI award rates at the individual level.

standards were significantly relaxed for workers above age 57 relative to those below age 57. In 2013 the Austrian government increased the age threshold for relaxed DI access from age 57 to age 58, followed by further increases to age 59 in 2015 and age 60 in 2017. These step-wise increases imply that the strictness of DI eligibility at a certain age varied by date of birth. On this basis, our estimation approach is a difference-in-differences design, comparing younger and older birth cohorts, who faced different DI eligibility rules, over time.

Our identification strategy to analyze the impact of benefit generosity exploits variation in DI benefits arising from a large pension reform that changed DI benefit levels for individuals with similar characteristics in different ways. This allows us to use a difference-in-differences approach that relates individuals' labor supply response to their differential change in benefit levels stemming from the policy reform.

The insights from our empirical analysis can be summarized by five broad conclusions. *First*, DI benefit receipt is responsive to changes in DI eligibility criteria. We estimate that tightening DI eligibility standards at age 57 reduces the receipt of DI benefits between age 57 and 61 by 2.5 percentage points (about 13 percent of the DI benefit receipt above the RSA), increases employment by 1.85 percentage points and creates substitution to other social insurance benefits (0.95 percentage points). *Second*, DI applications respond to the stricter criteria. This implies that the reduction in DI benefit receipt is both driven by a behavioral (fewer individuals apply) and a mechanical effect (fewer individuals are awarded DI benefits). Interestingly, applications are not only lower at age 57, when the eligibility criteria change, but this effect persists up to age 61. *Third*, our complier analysis suggests that the least sick individuals react to the stricter DI eligibility criteria by no longer applying. *Fourth*, we find that DI applications and DI claiming are also sensitive to the level of DI benefits. *Fifth*, we find that stricter eligibility rules create fiscal multipliers of 2-2.5 and reducing benefit generosity generates fiscal multipliers of 1.3-1.4. This implies that by increasing strictness of eligibility rules the policy maker can induce larger behavioral changes and generate greater cost reductions compared to reducing DI benefits. Hence, on the cost side stricter eligibility rules are more effective. Reducing benefit generosity is only preferable to stricter eligibility rules if the insurance loss of reducing benefits was more than 1.1 dollars smaller than the insurance loss induced by stricter eligibility rules.

There is a growing empirical literature studying the effects of DI on labor market outcomes (e.g. (Autor and Duggan, 2003; de Jong, Lindeboom, and van der Klaauw, 2011; Staubli, 2011; Maestas, Mullen, and Strand, 2013; Moore, 2015; Gelber, Moore, and Strand, 2017)) but empirical evidence on the effect of eligibility criteria on DI application behavior is scarce. Also, from a theoretical perspective relatively little is known about how imperfect information on disability status should be used to solve the incentive-insurance trade-off in the DI program. Diamond and Sheshinski (1995) and Parsons (1996) discuss medical screening in a static environment. More recently, Denk and Michau (2013) and Low and Pistaferri (2015) assess the optimal screening stringency in a dynamic environment and both conclude that screening stringency is too strict in the U.S. This paper builds on this literature and adds to it by exploring how changes in eligibility criteria and benefit levels affect DI application behavior and labor market outcomes of applicants. In particular, we are able to examine the relative impact of stricter eligibility criteria on DI enrollment due to more people being denied benefits under the stricter rules as opposed to more people self-screening, i.e. not applying for benefits. Moreover, our theoretical framework shows how our empirical estimates relate to welfare effects of such reforms.

The paper is organized as follows. The next section presents a model of disability insurance and formulae for optimal disability screening and benefits. Section 3.3 describes the data and institutional background in Austria. Sections 3.4 and 3.5 present the empirical results on stricter disability screening and changes in benefit levels, respectively. Section 3.6 estimates the fiscal multipliers of stricter screening and reduced benefits and discusses how our estimates can be used for welfare evaluation. Section 3.7 concludes.

3.2 Theoretical Framework

In this section, we explore how the two main DI policy parameters – the strictness of DI eligibility rules and the level of DI benefits – affect social welfare, as well as labor supply and application behavior of potential DI claimants.[4] Section 3.2.1 uses the static framework of Diamond and Sheshinski (1995) to illustrate the basic trade-offs, characterizes the socially optimal policy mix and derives sufficient-statistics formulas. Section 3.2.2 extends the static framework to a dynamic setting with a sequence of (health and economic) shocks showing that the basic trade-offs highlighted in the static model carry over to more general environments.

3.2.1 A Static Model of Optimal DI

Setup. Consider an agent living for two periods. In the first period, she works, earns a wage w, pays a lump-sum tax τ (which finances the DI program) and enjoys utility $u(w-\tau)$. There are no savings nor any other choices in the first period.[5] In the second period, the agent suffers a disability shock θ, modeled as a random draw from a continuous distribution $F(\theta)$. Figure 3.1 details the sequence of events and agent's choices in the second period. If θ is small (= the disability not very severe), the agent continues working and enjoys second-period utility $u(w)-\theta$. If θ is sufficiently large (= the disability severe), the agent applies for DI benefits. A DI application causes disutility ψ, capturing the extensive medical checks, the bureaucratic hassle, etc. associated with the DI assessment process. The fixed welfare cost ψ is important in the present context as it ensures that DI application choices depend on the generosity of the DI system.[6] With probability $p(\theta)$ the application is accepted, where $p'(\theta) > 0$.[7] When the application is accepted, the agent withdraws from work, claims DI benefits b and gets second-period utility $v(b)-\psi$. When the application is rejected, the applicant either resumes work and gets second-period utility $u(w)-\theta-\psi$; or claims social welfare $z < b$ and gets second-period utility $v(z)-\psi$. (No disutility or uncertainty are associated with claiming social welfare .)

Notice that the decision tree of Figure 3.1 assumes that the social welfare program is a safety net to which an agent only applies after a DI application is rejected. It is useful to make explicit the condition under which claiming social welfare is a "second choice" for any agent. The utility of claiming social welfare falls short of the utility of working if the agent's disability is $\theta < \theta^R \equiv u(w) - v(z) > 0$. Hence, θ^R is the "marginal social welfare claimant". If $\theta \geq \theta^R$ the agent prefers social welfare over working and vice versa. An agent with $\theta \geq \theta^R$ applies to DI if $v(z) < p(\theta)\, v(b) + [1-p(\theta)]\, v(z) - \psi$ (the utility on social welfare falls short of the expected utility of applying to DI). If this latter condition holds for $\theta = \theta^R$, it also holds for $\theta > \theta^R$, because $p'(\theta) > 0$ and $b > z$. Thus, no agent will claim social welfare benefits unless a previous DI application has been rejected (= the situation depicted in Figure 1), if

$$\psi < p(\theta^R)\, [(v(b) - v(z)]\,. \tag{3.1}$$

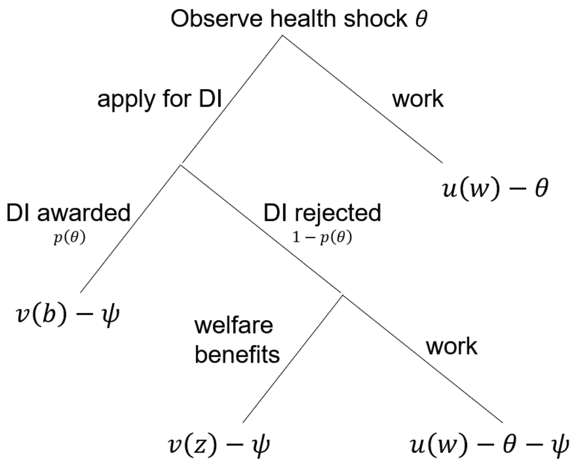
[4] By increasing the "strictness of disability rules" we mean any policy making it more difficult that a DI application – with a given degree of disability – gets accepted. This is what Low and Pistaferri (2015) and Diamond and Sheshinski (1995) call, respectively, "strictness of screening" and "disability standard". The terms disability rules, disability standard, and disability screening are used interchangeably. The formal definition of strictness is discussed in detail in section 3.2.1.

[5] The setup follows Chetty (2006) who reconsiders Baily's (1978) formula of optimal unemployment insurance (UI). The stylized two-period framework - tax payments but no DI application choices in the first period, while no tax payments but DI application choices in the second period - simplifies the formula without changing the substance of the argument.

[6] Here we deviate from Diamond and Sheshinski (1995) who do not consider application costs. Recent empirical studies support the idea that application costs are important drivers of DI applications, e.g. Deshpande et al. (2019) and Godard et al. (2019).

[7] Below, we will analyze a situation where the government has control over the $p(\theta)$-function. By adopting stricter eligibility rules, the $p(\theta)$-function shifts down, so that p takes a lower value for any given θ (and vice versa).

Figure 3.1: Decision Tree Model



Note: This figure shows the decision tree of the second period in the static model. If the disability level θ is small, the agent continues working and enjoys utility $u(w) - \theta$. If the disability is severe an agent applies to DI and is accepted with probability $p(\theta)$. Second period utility is $v(b) - \psi$in case of acceptance into DI. If the agent's application is rejected, she needs to decide whether to return to work (with utility $u(w) - \theta - \psi$) or consume other social welfare benefits (with utility $v(z) - \psi$).

The condition is intuitive: if the DI program is generous (low ψ, high $p(\theta)$ and high b) and/or the social welfare program restrictive (low z), an agent with a severe disability first tries to get on DI, and claims social welfare only if her DI application gets denied. In what follows, we assume condition (1) is satisfied.

DI Applications and Labor Supply. Let us now look at the DI application choice. Consider an agent whose disability is not extremely severe, $\theta < \theta^R$. (This implies she goes back to work in case her DI application gets rejected.) Her application choice compares the utility when staying employed, $u(w) - \theta$, to the expected utility when applying for DI, $p(\theta)\, v(b) + [1 - p(\theta)]\,(u(w) - \theta) - \psi$. The "marginal applicant," the agent who is indifferent between filing a DI application and remaining employed, has disability

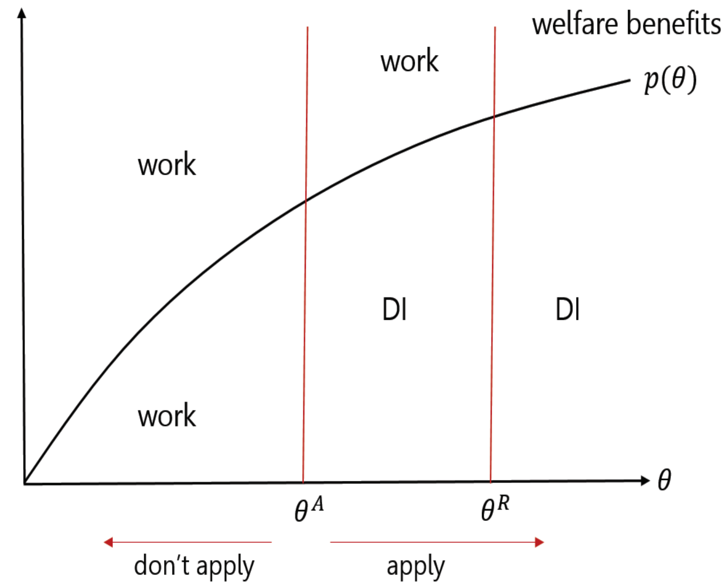
$$\theta^A = u(w) - v(b) + \frac{\psi}{p(\theta^A)}. \tag{3.2}$$

It follows that agents with disability $\theta \geq \theta^A$ apply for DI, while agents with disability $\theta < \theta^A$ remain employed. Figure 3.2 characterizes the outcome of agents' DI application choices. It draws the probability of DI award $p(\theta)$ against θ and indicates the disability cutoff-levels θ^A and θ^R. Agents with a disability $\theta \geq \theta^A$ apply for DI; if rejected, those with disability $\theta \in \left[\theta^A, \theta^R\right)$ return to work, while those with $\theta \geq \theta^R$ go on social welfare.

Equation (3.2), and its graphical representation in Figure 3.2, applies when $\theta^A < \theta^R$, i.e. a marginal applicant returns to work in case her DI application is rejected. Indeed, this outcome will arise as long as condition (3.1) holds.[8] It is worth emphasizing that condition (3.1) is the natural assumption in the present context. When this condition holds, the model predicts that DI

[8] To see this, consider the alternative scenario, $\theta^A \geq \theta^R$, in which a rejected marginal applicant claims social welfare. In that scenario, the marginal applicant is indifferent between applying for DI and claiming social welfare, $p(\hat{\theta}^A)]v(b) + [1 - p(\hat{\theta}^A)]v(z) - \psi = v(z)$ or $\psi = p(\hat{\theta}^A)\,[v(b) - v(z)]$, where $\hat{\theta}^A$ is the corresponding threshold

Figure 3.2: Illustration of model



Note: This figure illustrates the basic setup. Individuals are characterized by disability level θ and can choose whether to work, apply to DI or leave the labor force and consume social welfare benefits. The award process to DI is noisy and individuals are awarded DI with probability $p(\theta)$. We assume that $p(\theta)$ is weakly increasing in θ. This captures that (i) it is difficult to assess the true disability level of an individual and (ii) the assessment contains nonetheless some valuable information on the true disability level. The marginal DI applicant is denoted by θ^A and individuals with $\theta \geq \theta^A$ apply to DI. The marginal welfare benefits type is denoted by θ^R and individuals with $\theta \geq \theta^R$ will go on welfare benefits if they are rejected.

policy parameters affect labor supply decisions. Distortionary labor supply effects of DI programs are supported by a large body of empirical evidence.[9]

DI Policy Instruments. We now assess the welfare effects of two policy instruments that characterize any DI system: the level of DI benefits and the strictness of DI eligibility rules. While the role of DI benefits b is straightforward and poses no major conceptual problems, the role of DI eligibility rules θ^* needs further discussion. The inherent problem of the DI assessment process is that the true disability θ is the agent's private information. For this reason, a DI applicant has to undergo a disability assessment process, which delivers an estimate of her disability to the government. Formally, the government observes $s = \theta + e(\theta)$, where s is a noisy signal, θ is the applicant's true disability and $e(\theta)$ is the noise.[10] Define by $G(s|\theta)$ the (continuous) cumulative distribution of signals s among a pool of applicants with disability θ.[11] In the following we assume

disability. However, this latter equality – together with $p(\hat{\theta}^A) \geq p(\theta^R)$ – implies that condition (3.1) is violated. In other words, while this alternative scenario is possible in principle, it is ruled out under the maintained parameter constellation. The intuition is similar as before: if the DI system is generous and/or social welfare restrictive, the rejected marginal applicant goes back to employment.

[9]A number of papers provide direct evidence on the work behavior of rejected DI applicants. These findings are perfectly consistent with the predictions of the model under condition (3.1). Bound (1989); von Wachter et al. (2011); Maestas et al. (2013); French and Song (2014) use rejected DI applicants as a control group for accepted applicants to study the impact of DI on labor supply. For instance,von Wachter et al. (2011) report that, in 69.6% of rejected DI applicants aged 30-44 in the US report positive yearly earnings two years after the DI application and 57.4% report earnings higher than three months of full-time employment at the minimum wage in 2000. The corresponding numbers are 52.6% and 42.7% for rejected DI applicants aged 45-64. In the Norwegian study by Kostol and Mogstad (2014), about 30 percent of rejected DI applicants aged 18-49 are participating on the labor market.

[10]The variance of the noise is likely to vary with the severity of the disability as very severe and perhaps also very weak disabilities are more easy to assess than intermediate cases.

[11]Formally, $G(s|\theta)$ is the marginal distribution of s with respect to a given level of θ of the bivariate distribution of s and θ.

that the DI assessment process is informative, i.e. we assume $\partial G(\bar{s}|\theta)/\partial\theta < 0$. This implies that in an applicant pool with a more severe disability a smaller fraction of DI assessments fall short of an arbitrary cutoff $\bar{s}$ and will ensure that on average the award probability is increasing in the severity of the disability.

The strictness of DI eligibility rules – the policy parameter under direct control of the government – can be captured by a critical value of s, call it θ^*, such that a DI application with $s \geq \theta^*$ is accepted, while an application with $s < \theta^*$ is rejected. The acceptance probability can then be written as $p(\theta;\theta^*) = 1 - G(\theta^*|\theta)$. In what follows, we consider the case where the government can change θ^* but takes $G(s|\theta)$ as given. This is the context of our empirical anlaysis below, which exploits quasi-experimental variation in the "relaxed screening age" (RSA) at which DI eligibility rules become more lenient. In our notation, the strictness of DI eligibility equals $\theta^* = \theta^H$ before the RSA and falls to $\theta^L < \theta^H$ after the RSA. An increase in the RSA from age R to some higher age $R + \Delta$, implies that, during the age window $[R, R + \Delta]$, the treated cohort is subject to the strict DI eligiblity standard θ^H, while the control cohort is subject to the lenient standard θ^L. If cohorts are otherwise similar (in productivity, health, preferences, etc.), a plausible assumption for "adjacent" cohorts, comparing treated to control cohorts identifies the causal effect of an increase in θ^* on the outcomes of interest.

It should be clear that the government could, in principle, take measures other than varying θ^* to manipulate the DI award probability $p(\theta;\theta^*)$. For instance, the goal of a DI reform could be to increase the precision of DI screening, to avoid type-I and type II errors (= false acceptances and false rejections) of an imperfectly functioning DI assessment system. This could be done through more extensive medical checks, better equipment, monitoring of DI applicants, etc.. Such measures would change the function $G(s|\theta)$ by reducing the variance of the noise $e(\theta)$. However, unlike changing θ^*, changing $G(s|\theta)$ requires resources and welfare calculations need to take into account society's willingness to pay for improved DI screening. While such policies are clearly relevant in practice, we do not analyze their welfare implications here, mainly because we cannot address them empirically with our data. However, we consider this a potentially interesting direction for future research.

Welfare Effects of DI Reforms. We follow the literature assuming society's objective can be represented by a utilitarian social welfare function. Assuming a population of mass unity and abstracting from discounting, the social welfare function is given by

$$\begin{aligned} W(\theta^*, b) = \quad & u(w-\tau) + \textstyle\int_0^{\theta^A} (u(w) - \theta) dF(\theta) + \int_{\theta^A}^{\theta^R} (1 - p(\theta;\theta^*))(u(w) - \theta) dF(\theta) + \\ & + \textstyle\int_{\theta^A}^{\infty} p(\theta;\theta^*) v(b) dF(\theta) + \int_{\theta^R}^{\infty} (1 - p(\theta;\theta^*)) v(z) dF(\theta) - \int_{\theta^A}^{\infty} \psi dF(\theta). \end{aligned} \tag{3.3}$$

The right-hand-side terms sum up the welfare levels of the various agents: first-period workers, all of whom are working and paying taxes (first term on the right-hand-side); the working healthy (second term), the rejected DI applicants resuming work (third term); the DI recipients (fourth term); and the social-welfare recipients (fifth term). The last term takes account of the aggregate welfare losses associated with DI application costs. When designing the optimal DI program, the government needs to take into account agents' behavioral responses to changes in DI policy parameters. Furthermore, the social planner is constrained by a balanced-budget requirement: DI and social welfare benefit payments have to be covered by the taxes raised in the first period,

$$\tau = b \int_{\theta^A}^{\infty} p(\theta;\theta^*) dF(\theta) + z \int_{\theta^R}^{\infty} (1 - p(\theta;\theta^*)) dF(\theta). \tag{3.4}$$

.

In what follows, we discuss the welfare effects of DI reforms. We first look at the effects of implementing more stringent DI eligibility rules, before we turn to the effects of reducing DI benefits. Finally, we discuss optimal policy mix of DI reforms when θ^* and b are changed simultaneously. The discussion is framed in terms of implementing a more restrictive DI system, because most policy debates center around releasing the financial burden of the DI program. Of course, analogous arguments hold for reforms that increase the generosity of the DI system.

Stricter DI Eligibility Rules. The utilitarian government sets DI eligibility rules θ^* to maximize social welfare W, taking into account the balanced-budget requirement and agents' DI application responses. In Appendix 3.B.1, we show that the welfare effect of increasing θ^* is

$$\frac{\partial W}{\partial \theta^*} = u'(w-\tau) \underbrace{[B(\theta^*)+M(\theta^*)]}_{\text{fiscal cost reduction}} - \underbrace{\left[[v(b)-(u(w)-\tilde{\theta})]M_W + [v(b)-v(z)]\,M_Z\right]}_{\text{insurance losses}} \tag{3.5}$$

Condition (3.5) highlights the two opposing effects of stricter DI eligiblity rules θ^* on social welfare. On the one hand, a higher θ^* raises social welfare because it saves taxpayers' money (fiscal cost reduction). On the other hand, a higher θ^* reduces social welfare, because fewer agents are awarded DI when hit by a severe disability shock (insurance losses).

The fiscal cost reduction consist of two components: the behavioral fiscal effect $B(\theta^*)$ and the mechanical fiscal effect $M(\theta^*)$. The behavioral fiscal effect measures the reduction in DI expenditures due to fewer DI applications. The mechanical fiscal effect $M(\theta^*)$ comes from fewer DI applications getting accepted. To see the behavioral and mechanical effects more clearly, note that the DI inflow probability is the product of two factors: the probability of filing an application times the probability that the application gets accepted, $Pr(\text{DI}) = Pr(\text{Apply}) * Pr(\text{Accept}|\text{Apply})$. In the above notation, the application probability is $Pr(\text{Apply}) = 1 - F(\theta^A)$, while the acceptance probability is $Pr(\text{Accept}|\text{Apply}) = \left[\int_{\theta^A}^{\infty} p(\theta;\theta^*)dF(\theta)\right] / \left[1-F(\theta^A)\right]$. The derivative of the application probability with respect to θ^* yields the average agent's change in application behavior, $(\partial\theta^A/\partial\theta^*)p(\theta^A;\theta^*)f(\theta^A)$, which is the red area of Figure 3.3. Multiplying with the DI benefit b yields the behavioral fiscal effect $B(\theta^*) = (\partial\theta^A/\partial\theta^*)p(\theta^A;\theta^*)f(\theta^A)\cdot b$. The derivative of the acceptance probability with respect to θ^* equals $-\int_{\theta^A}^{\infty}(\partial p(\theta;\theta^*)/\partial\theta^*)dF(\theta)$, which is the sum of the grey and the blue area of Figure 3.3. The grey area captures the rejected working applicants $M_W \equiv -\int_{\theta^A}^{\theta^R}(\partial p(\theta;\theta^*)/\partial\theta^*)dF(\theta)$; the blue area are the rejected applicants on social welfare $M_Z \equiv -\int_{\theta^R}^{\infty}(\partial p(\theta;\theta^*)/\partial\theta^*)dF(\theta)$. Each rejected applicant resuming work saves the amount b to the taxpayer (recall that, in the second period, workers do not pay taxes), while each rejected applicant substituting DI for social welfare saves $b - z > 0$ to the taxpayer. The mechanical *fiscal* effect is therefore $M(\theta^*) \equiv M_W \cdot b + M_Z \cdot (b-z)$. Since fiscal savings are used to reduce taxes, the total fiscal gain, $B(\theta^*) + M(\theta^*)$, is valued at the marginal utility of consumption of the taxpayer $u'(w-\tau)$ in equation (3.5).

Adopting stricter DI elgibility rules θ^* does not only save money to taxpayers, it also reduces the insurance value of the DI system. The lower DI acceptance probability corresponds to a higher probability that a DI applicant eventually has to resume work, M_W, or has to claim social welfare, M_Z. The average utility loss of the former is $v(b)-(u(w)-\tilde{\theta}) > 0$, where $\tilde{\theta}$ is the average disability level of rejected applicants who go back to work.[12] The utility loss of the latter is $v(b) - v(z) > 0$. Note the reduction in the insurance value depends only on the mechanical effect but not on the behavioral effect. This is a direct implication of the Envelope theorem.[13] Intuitively, only marginal applicants react to a marginal change in the strictness of screening. Marginal applicants are indifferent between applying and not applying. Hence, if a marginal increase in θ^* induces them not to file an application, their welfare is not directly affected. However, fewer applications reduce the financial burden of the DI system, thus they generate a positive fiscal effect that benefits taxpayers.

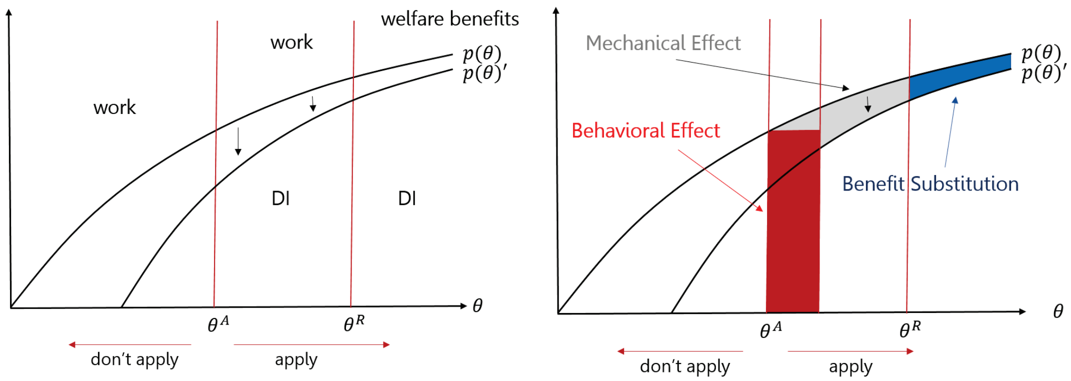
The optimal strictness of screening θ^* balances the trade-off between insurance loss and fiscal gain, where (3.5) is set to zero. For later use, we rewrite this condition as

[12] Formally, $\tilde{\theta}$ is the average disability level of agents with a disability shock in the range $\left[\theta^A, \theta^R\right)$, so that $\tilde{\theta} \equiv \int_{\theta^A}^{\theta^R}(\partial p(\theta;\theta^*)/\partial\theta^*)\theta dF(\theta) / \int_{\theta^A}^{\theta^R}(\partial p(\theta;\theta^*)/\partial\theta^*)dF(\theta)$.

[13] While the decision to apply is discrete the envelope theorem applies because we have a marginal change in the policy parameter θ^*. In Appendix 3.B.1 we show this formally and also discuss how the welfare evaluation changes in case of a discrete (non-marginal) change of θ^*.

Figure 3.3: Effects of stricter screening

(a) Shift of award probability curve (b) Different effects



Notes: The figure illustrates the effects of stricter screening. Stricter screening shifts down the award probability curve (Panel a). The area between the two award probability curves is the mechanical effect. Panel b illustrates the different effects of stricter screening. A fraction of rejected applicants due to the mechncial effect returns to work (gray area). The other fraction substitutes DI benefits with welfare benefits (blue area). Stricter screening also shifts the marginal applicant to the right. The change in the marginal applicant times the award probability of the marginal applicant is the behavioral effect (red area).

$$\frac{\partial W}{\partial \theta^*} \gtreqless 0 \iff 1 + \frac{B(\theta^*)}{M(\theta^*)} \gtreqless \frac{L_W + L_Z}{u'(w-\tau)M(\theta^*)}, \tag{3.6}$$

where $L_W \equiv [v(b) - (u(w) - \tilde{\theta})]M_W > 0$ and $L_Z \equiv [v(b) - v(z)]\, M_Z > 0$ are the aggregate utility losses suffered by the additionally rejected applicants resuming work (L_W) and claiming social welfare (L_Z), respectively. The two sides of the inequality have an intuitive interpretation. The left-hand-side is the fiscal multiplier, $1 + B(\theta^*)/M(\theta^*)$, and measures the reduction in the financial burden for the taxpayer per *mechanically* saved dollar (= hypothetical fiscal gain when application behavior remains unchanged). The right-hand-side is the corresponding reduction of the insurance value in monetary units. Dividing by the marginal utility of consumption of the taxpayer $u'(w-\tau)M(\theta^*)$ yields the insurance loss (in monetary terms) per mechanically saved dollar.

Lower DI Benefits. The second key DI policy parameter is the level of DI benefits b. It is straightforward to show (see Appendix 3.B.1) that the condition for a socially optimal DI benefit level is

$$\frac{\partial W}{\partial(-b)} \gtreqless 0 \iff 1 + \frac{B(b)}{M(b)} \gtreqless \frac{v'(b)}{u'(w-\tau)}. \tag{3.7}$$

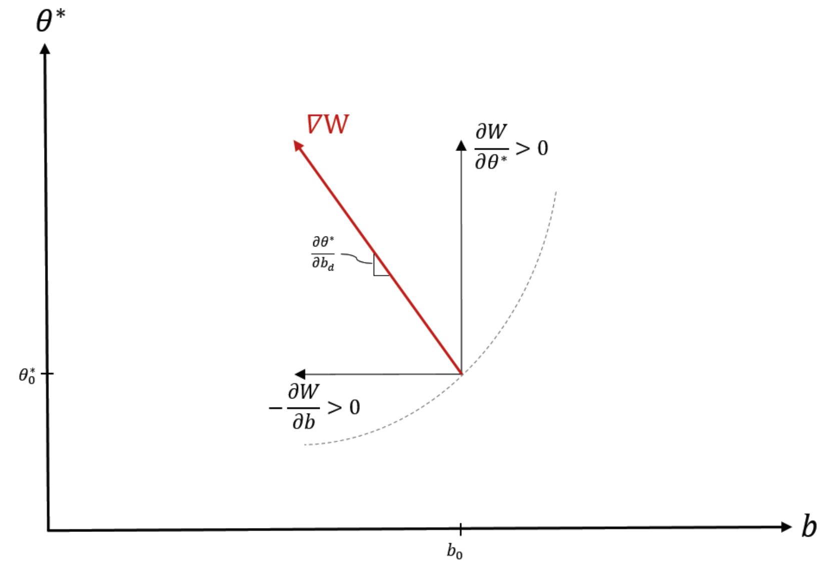
Similar to condition (3.6) above, condition (3.7) tells us that a reduction in DI benefits b is welfare-improving if the fiscal gains to taxpayers exceeds the insurance loss suffered by disabled workers. On the one hand, a lower b reduces the financial burden of the DI system because fewer agents apply for DI. In condition (3.7), this is captured by the fiscal multiplier, $1 + B(b)/M(b)$. On the other hand, a lower b reduces the consumption smoothing benefit, because it reduces the consumption possibilities when hit by disability shock. This is captured by the ratio of marginal utilities of a DI benefit recipient relative to the one of a taxpayer.

The behavioral fiscal effect is $B(b) \equiv -\left(\partial\theta^A/\partial b\right) p(\theta^A) f(\theta^A) \cdot b$ and the mechanical fiscal effects is $M(b) \equiv \int_{\theta^A}^{\infty} p(\theta) dF(\theta)$. The ratio of behavioral over mechanical fiscal effect corresponds to the DI inflow elasticity, i.e. $\xi = (\partial DI/\partial b)(b/DI) = -\left(\partial\theta^A/\partial b\right) p(\theta^A) f(\theta^A) b / \int_{\theta^A}^{\infty} p(\theta) dF(\theta) = B(b)/M(b)$. This yields an interesting analogy of the optimal DI formula to the famous Baily (1978) formula for optimal unemployment insurance (UI). Both in the case of UI and in the case of DI, the condition for the socially optimal benefit level can be written as $1+\eta = v'(b)/u'(w-\tau)$. In the Baily (1978) model of optimal UI, η is the elasticity of unemployment duration with respect to the UI benefit level; in the above model of optimal DI, $\eta = \xi$, the elasticity of the DI inflow with respect to the DI benefit level. In other words, the relevant moral-hazard margin in the case of DI is the program *inflow*, while the relevant margin in the case of UI is the program *outflow*.[14]

Optimal DI Policy Mix. So far, we have derived conditions for social optimality for each single DI policy parameter, holding the other policy parameter fixed. However, a natural question is how a DI reform should optimally combine these two policy parameters. More precisely: how strongly – and in which direction – should DI eligibility rules θ^* be changed per unit change of DI benefits b?

Figure 3.4 illustrates the idea. It depicts the current policy (θ_0^*, b_0). The dotted curve indicates the combinations of (θ^*, b) that generate the same level of social welfare. Consider the effect of a DI reform starting from the pre-reform DI policy is (θ_0^*, b_0). The vertical (horizontal) arrow shows how θ^* (b) needs to be changed to increase welfare. In Figure 3.4 the vertical arrow points up and the horizontal arrow points to the left, indicating that a welfare-enhancing DI reform implement lower benefits and stricter eligibility rules.[15] The length of the arrows correspond to the effectiveness of the respective policy instrument. In Figure 3.4 the horizontal arrow is short, while the vertical arrow is long, suggesting that the DI reform should strongly increase θ^* per unit reduction of b. The slope of the gradient – the arrow pointing to the northwest – yields the optimal policy mix.

Figure 3.4: Optimal policy mix – gradient of welfare function



Notes: The figure illustrates the idea of the optimal policy mix. It shows the gradient in case screening should be stricter and benefits should be less generous. The dashed line is the indifference curve of the welfare function of the current benefit level and strictness of screening. The gradient of the welfare function is orthogonal to the indifference curve and points in the direction of greatest increase of the function.

[14]The implicit assumption here is that DI generosity does neither affect the intensive margin of labor supply (DI recipients do not work on the labor market) nor the outflow from DI (DI is an absorbing state, no DI spell ever terminates to a regular job or any other destination).

[15]Alternatively, if the horizontal arrow points to the right and the vertical arrow points up, the existing DI system is too restrictive in both dimensions and a welfare reform increasing DI benefits and implementing more lenient DI eligibility rules is welfare improving. Of course, all other permutations are possible.

Using the first order conditions equations (3.6) and (3.7), the gradient is given by

$$\nabla W = \begin{pmatrix} -\partial W/\partial b \\ \\ \partial W/\partial \theta^* \end{pmatrix} = \begin{pmatrix} \sigma \cdot M(b) \\ \\ \gamma \cdot M(\theta^*) \end{pmatrix} u'(w-\tau) \tag{3.8}$$

where σ and γ measure the gap between fiscal gains and insurance loss for changes in b and θ^*, respectively. Formally, we have $\sigma \equiv [1 + B(b)/M(b)] - [v'(c_d)] / [u'(w-\tau)M(b)]$ and $\gamma \equiv [1 + B(\theta^*)/M(\theta^*)] - [L_W + L_Z] / [u'(w-\tau)M(\theta^*)]$. Therefore, the optimal DI policy mix is given by the ratio

$$\left.\frac{\partial \theta^*}{\partial b}\right|_{opt} = \frac{\gamma}{\sigma} \cdot \frac{M(\theta^*)}{M(b)}. \tag{3.9}$$

The sign of σ determines the direction in which benefits should be adjusted (if $\sigma \gtrless 0 \Leftrightarrow -\partial W/\partial b \gtrless 0 \Leftrightarrow \partial b \lesseqgtr 0$). Similarly, the sign of γ determines the direction of adjustment in θ^* (if $\gamma \gtrless 0 \Leftrightarrow \partial W/\partial \theta^* \gtrless 0 \Leftrightarrow \partial \theta^* \gtrless 0$). Hence, σ and γ determine the direction of welfare-enhancing adjustments in b and θ^*, while the ratio γ/σ determines the optimal DI policy mix, $(\partial\theta^*/\partial b)_{opt}$. b and θ^* have different units. Hence, for a meaningful interpretation of the optimal direction we normalize by the respective mechanical fiscal effects of a one unit change in b and θ^* respectively. This means that the optimal direction is expressed in terms of a mechanical 1 dollar change in fiscal costs: For a mechanical one dollar reduction in fiscal costs due to lower benefits, screening should be adjusted such that fiscal costs are mechanically reduced by $\frac{\gamma}{\sigma}$ dollars.

3.2.2 The General Model

The above model highlights the basic trade-offs of DI policy reforms but misses two ingredients that are crucial in designing and evaluating DI reforms: heterogeneity across individuals and intertemporal choices. In the model of section 3.2.1, agents differ only in θ and all actions happen within one period. In what follows, we allow for multiple sources of heterogeneity (such as wages and other factors) and we extend the model to multiple periods. This latter extension allows us to capture the intertemporal nature of the DI application choice. In the context of our empirical analysis below – which exploits an RSA increase from R to some higher age $R + \triangle$ – it is obvious, that the question "When should I apply?" becomes crucial. To address the DI application timing in a meaningful way, a dynamic framework is needed.

Agents' Choices and Social Welfare. Assume that the agent's time horizon consists of T periods, indexed by $t = 0, \ldots, T-1$. Denote by $\theta_{i,t}$ the disability shock, by $\chi_{i,t}$ a vector of other shocks (such as wages/productivity and other factors) influencing the DI application choice, and by $A_{i,t}$ the level of financial assets available at the beginning of period t. Once the state vector $X_{i,t} = (\theta_{i,t}, A_{i,t}, \chi_{i,t})$ is revealed, agent i decides whether to apply for DI, and if rejected, whether to resume work or claim social welfare. The application and work decisions are based on knowledge of $X_{i,t}$ and expectations about future realizations of $X_{i,t+s}$, $s = t+1, \ldots, T-1$. Simultaneously with the DI application choice, the agent decides how much to consume and save in period t.[16] The decisions in period t determine $A_{i,t+1}$ and, together with realizations $\theta_{i,t+1}$ and $\chi_{i,t+1}$, form the state vector X_{t+1}, on the basis of which the agent makes her $t+1$ choices, and so on.

The utilitarian government can freely chose DI policy parameters $P = (\theta_0^*, \ldots, \theta_{T-1}^*; b_0, \ldots, b_{T-1})$ and seeks to maximize the objective

$$\max_P W(P) = \int_i V_i(P) di + \lambda \left(G(P) - \bar{G}\right), \tag{3.10}$$

[16] The within-period sequence of work and DI-application choices is just like the one of the static model, captured in Figure 3.1. However, the general model also admits the possibility that $\theta^A \geq \theta^R$, so that equation (3.1) is violated. This might occur for agents with low wage realization and low DI acceptance probabilities.

where $W(P)$ denotes social welfare under policy P; $V_i(P)$ is the (expected) indirect lifetime utility of agent i (who responds optimally to policy P), λ is the Lagrange multiplier on the government's budget constraint, $G(P)$ is the net fiscal revenue, and $\bar{G}$ is an exogenous revenue constraint. $G(P)$ is given by

$$G(P) = \int_i E\left[\sum_{t=0}^{T-1} (1+r_t)^{-t} \left(W_{i,t} \cdot \tau_{i,t} - D_{i,t} \cdot b_{i,t} - Z_{i,t} \cdot z_{i,t}\right)\right] di, \tag{3.11}$$

where $(D_{i,t}, W_{i,t}, Z_{i,t})$ denote the probabilities that in period t agent i is on DI, at work or on social welfare. In Appendix 3.B.2 we show that agent i's indirect (expected) lifetime utility can be written as

$$\begin{aligned} V_i(P) \quad = \quad & \max E\left[\sum_{t=0}^{T-1} \beta^t \left(v(c_{i,t}^D) \cdot D_{i,t} + v(c_{i,t}^Z) \cdot Z_{i,t} + \left(u(c_{i,t}^W) - \theta_{i,t}\right) \cdot W_{i,t} - \Lambda_{i,t} \cdot \psi\right)\right] \quad (3.12) \\ & + E\left[\sum_{t=0}^{T-1} \beta^t \mu_{i,t}^D \left((1+r_t)A_{i,t} + b_{i,t} - c_{i,t}^D - A_{i,t+1}\right) D_{i,t}\right] \\ & + E\left[\sum_{t=0}^{T-1} \beta^t \mu_{i,t}^W \left((1+r_t)A_{i,t} + w_{i,t} - \tau_{i,t} - c_{i,t}^W - A_{i,t+1}\right) W_{i,t}\right] \\ & + E\left[\sum_{t=0}^{T-1} \beta^t \mu_{i,t}^Z \left((1+r_t)A_{i,t} + z_{i,t} - c_{i,t}^Z - A_{i,t+1}\right) Z_{i,t}\right], \end{aligned}$$

where the first line summarizes agent $i's$ period utilities, with $(c_{i,t}^D, c_{i,t}^W, c_{i,t}^Z)$ as the consumption levels in the various states, and $\Lambda_{i,t}$ as the DI application indicator. The remaining lines are agent i's budget constraints associated with being on DI (second line), at work (third line), and on social welfare (fourth line). The corresponding Lagrangian multipliers are denoted by $(\mu_{i,t}^D, \mu_{i,t}^W, \mu_{i,t}^Z)$.

Stricter DI Eligibility Rules. We now explore the welfare effects of marginally changing the strictness of DI eligibility rules θ_s^*, while leaving all other elements of the DI policy vector $P = (\theta_0^*, \ldots, \theta_{T-1}^*; b_0, \ldots, b_{T-1})$ unchanged. Notice that this thought experiment is equivalent to an RSA increase, the policy change we exploit below to empirically estimate the effect of stricter DI eligibility rules. An RSA policy implies that θ_t^* takes high values up until age $R-1$ and falls to lower values from age R onward. If the relaxed screening age is increased from age $R = s$ to $R = s+1$, this is equivalent to an increase in θ_s^* but unchanged values of $\theta_{t\neq s}^*$.[17] In Appendix 3.B.2 we show that $\partial W(P)/\partial \theta_s^* \gtreqless 0$ is equivalent to

$$1 + \frac{\mathbb{E}\left[B(\theta_s^*)\right]}{\mathbb{E}\left[M(\theta_s^*)\right]} \gtrless \frac{\mathbb{E}\left[L_W\right] + \mathbb{E}\left[L_Z\right]}{\lambda \cdot \mathbb{E}\left[M(\theta_s^*)\right]}, \tag{3.13}$$

where the operator $\mathbb{E}[Y]$ encompasses aggregation of the variable $Y_{i,t}$ across individuals, time and states of nature.[18] The left-hand-side is the fiscal multiplier of increasing θ_s^* where $\mathbb{E}[M(\theta_s^*)]$ denotes the mechanical fiscal effect and $\mathbb{E}[B(\theta_s^*)]$ is the behavioral fiscal effect. The right-hand side, $\mathbb{E}[L_W] + \mathbb{E}[L_Z]$ are the dynamic insurance losses arising from fewer agents being admitted to the DI program in period s. Normalizing by the Lagrange multiplier λ (= the value to society of relaxing the government budget constraint), yields the money-metric of these utility losses.

Notice the similarity of social optimality condition (3.13) of the general model with the social optimality condition (3.6) of the simple static framework. In the simple framework of section

[17] Notice further that our analysis in the text studies the welfare effects of a marginal increase θ_s^* while an RSA policy typically implies a discrete change in θ_t^* at the RSA. Assume that $\theta_t^* = \theta^H$ for ages $t = 0, \ldots, R-1$ and $\theta_t^* = \theta^L < \theta^H$ for ages $t = R, \ldots, T-1$. Then an increase in the RSA from $R = s$ to $R = s+1$ is associated with a discrete change in θ_s^* equal to $\triangle\theta_s^* = \theta^H - \theta^L$. We discuss the welfare effects of a discrete change in θ^* in Appendix 3.B.1 for the static model and in Appendix 3.B.2 for the general model. Our empirical implementation of the fiscal multiplier is robust to non-marginal changes. Kleven (2018b) discusses the issues when studying discrete rather than marginal changes in benefit levels.

[18] Formally $\mathbb{E}[Y] = \int_i \sum_{t=0}^{T-1} E(Y_{i,t}) di$ with $E(Y_{i,t}) = \int_{X(i,t)} Y(i,t) dF(X_{i,t})$.

2.1, agents differ only in θ and all actions happen within one period. In the general model, the time horizon extends to T periods and agents differ in arbitrarily many dimensions.[19] The key difference in the dynamic model is that an increase in θ_s^* – stricter DI eligibility rules at some age s – does not only affect the DI inflow at that age s, but also at other ages. Moreover, because DI is an absorbing state the mechanical effect of an increase in θ_s^* persists at older ages. If many applicants are screened out today, more applicants might reapply tomorrow. As a result, $\mathbb{E}\left[M(\theta_s^*)\right]$ is mechanically spread out over the age window $[s, T-1]$. It is instructive to formalize the dynamic of the mechanical effect here. Let $\alpha_{i,k}$ denote the application decision of individual i at age k ($\alpha_{i,k} = 1$ if apply and 0 otherwise) and $p_{i,k}$ denote the DI award probability of individual i at age k.[20] A marginal increase in θ_s^* reduces the award probability at age s by $\frac{\partial p_{i,s}}{\partial \theta_s^*}$ but leaves the award probabilities at all other ages unchanged. The mechanical effect at age s is then given by

$$\mathbb{E}\left[M_{i,s}\right] = \mathbb{E}\left[\frac{\partial p_{i,s}}{\partial \theta_s^*} \cdot \alpha_{i,s} \prod_{k=0}^{s-1} (1 - \alpha_{i,k} p_{i,k})\right],$$

the change in the award probability $\frac{\partial p_{i,s}}{\partial \theta_s^*}$ times the population at risk $\alpha_{i,s} \prod_{k=0}^{s-1} (1 - \alpha_{i,k} p_{i,k})$ (those who are not on DI already before age s ($= \prod_{k=0}^{s-1} (1 - \alpha_{i,k} p_{i,k})$) and apply to DI at age s ($\alpha_{i,s} = 1$)). This mechanical effect is persistent. At age $s+1$, $\mathbb{E}\left[M_{i,s+1}\right] = \mathbb{E}\left[(1 - \alpha_{i,s+1} p_{i,s+1}) M_{i,s}\right]$ fewer individuals are on DI because of the stricter screening at age s. The $M_{i,s}$ rejected individuals remain outside the DI program at age $s+1$ with probability $(1 - \alpha_{i,s+1} p_{i,s+1})$. This logic continues for all older ages. The mechanical effect at age $t > s$ is $\mathbb{E}\left[M_{i,t}\right] = \mathbb{E}\left[\frac{\partial p_{i,s}}{\partial \theta_s^*} \cdot \alpha_{i,s} \prod_{k=0, k \neq s}^{t} (1 - \alpha_{i,k} p_{i,k})\right]$. Therefore, the mechanical fiscal effect $\mathbb{E}\left[M(\theta_s^*)\right]$ can persist over multiple periods after s. The behavioral fiscal effect $\mathbb{E}\left[B(\theta_s^*)\right]$ can occur in all periods, even before age s, as forward-looking individuals might change their behavior already at younger ages. In Appendix 3.B.2, we make explicit how $\mathbb{E}\left[B(\theta_s^*)\right]$, $\mathbb{E}\left[M(\theta_s^*)\right]$, $\mathbb{E}\left[L_W\right]$ and $\mathbb{E}\left[L_Z\right]$ are determined. Our empirical analysis will shed light on the dynamics and timing of these effects. In Section 3.4 we estimate how stricter screening at a specific age affects fiscal costs, DI applications and labor market outcomes before and after that age. In Section 3.6, we decompose the estimated fiscal costs into the behavioral and mechanical fiscal effect and therefore provide direct evidence on how persistent the mechanical fiscal effect is. In section 3.6 we also discuss how our empirical estimates map to the dynamic model and can be used for welfare evaluation.

Lower DI Benefits. Alternatively, the DI reform may implement lower DI benefits. So let us consider the welfare effects of a reduction in the DI benefit b_s (while leaving DI benefits unchanged at all other ages). In Appendix 3.B.2 we show that that condition $\partial W(P)/\partial(-b_s) \gtreqless 0$ is equivalent to

$$1 + \frac{\mathbb{E}\left[B(b_s)\right]}{\mathbb{E}\left[M(b_s)\right]} \gtreqless \frac{\mathbb{E}\left[v'(c^D)\right]}{\lambda \cdot \mathbb{E}\left[M(b_s)\right]}, \tag{3.14}$$

where $\mathbb{E}\left[B(b_s)\right]$ and $\mathbb{E}\left[M(b_s)\right]$ are the behavioral and mechanical fiscal effects of a marginal reduction of b_s. Again, this looks very similar to the static model. Just like before, behavioral responses to a reduction of b_s occur in all periods. Mechanical responses occur at age s only (because we consider lower benefits paid out at age s but unchanged benefits at all other ages).

The optimal policy mix is analogous to the static model. It is simply the ratio of the generalized conditions (3.13) and (3.14) as we discuss in Appendix 3.B.2. Before turning to the empirical analysis of changes in strictness of screening and benefit generosity we describe the institutional background and data in the next section.

[19] In particular, the optimal DI formulas (3.13) and (3.14) let us calculate the welfare gains of DI reforms in a broad set of stochastic dynamic environments, such as investments in health or human capital (that might accommodate the disability and productivity shocks), borrowing constraints, spousal labor supply, home production, etc. In this respect, the analysis of optimal DI does not differ from the the case of optimal UI studied in Chetty (2006).

[20] $p_{i,k}$ is the short hand notation for $p(\theta_{i,k}; \theta_k^*)$.

3.3 Institutional Background and Data

Institutional Background. Like in many developed countries, Austria has three transfer programs that provide income replacement when separating from the labor market for economic or health reasons: disability insurance (DI), sickness insurance (SI), and unemployment insurance (UI). The DI program is financed by a payroll tax on earned income and provides partial earnings replacement to workers below the full retirement age who have accumulated at least 5 insurance years within the last 10 years. Insurance years include both contribution years (periods of employment, including sick leave and maternity leave) and non-contribution years (periods of unemployment, military service, or secondary education). The required insurance years increase by one month for every two months above age 50 up to a maximum of 15 insurance years.[21]

To apply for DI benefits, an individual must submit an application to the local DI office. Employees at the DI office first check whether the applicant is below the full retirement age and meets the insurance years requirement. DI eligibility is not conditioned on earnings, so applicants are not required to stop working in order to apply for benefits. In a second step, a team of disability examiners and physicians assesses the severity of the medical impairment and the applicant's residual earnings capacity. An impairment is considered to be severe if it lasts at least six months and limits the applicant's mental or physical ability to engage in substantial gainful activity.

The assessment of the applicant's residual earnings capacity depends on work experience and whether their age is below or above a *relaxed screening age (RSA)* threshold, currently set at age 60. Applicants below the RSA threshold are awarded benefits if the earnings capacity has been reduced to less than half of the earnings capacity of a healthy person in *any reasonable* occupation in the economy the individual could be expected to carry out. Eligibility standards are less strict for semi-skilled and skilled applicants below the RSA threshold, whose set of reasonable occupations is more limited.[22] Eligibility criteria are substantially relaxed for applicants above the RSA threshold who have worked in a *similar* occupation for 10 years in the last 15 years, by changing the comparison from a healthy worker in any reasonable occupation to a healthy worker in a similar occupation. An occupation is considered similar if the following requirements are identical: manual and mental demands, amount of responsibility, posture, concentration, endurance, required care, and stress level (Wörister, 1999). Older applicants are therefore more likely to be awarded benefits, because they are only compared to healthy workers in their occupation.[23] The RSA was 57 in 2004, but was increased in three one-year steps to 60 by 2017. In the empirical analysis, we exploit this variation in the RSA to identify the labor market effects of stricter disability screening (section 3.4). Once benefits are awarded, DI beneficiaries receive monthly payments until their return to work, medical recovery or death. DI benefits can be granted for a temporary period, but few claimants (less than 4 percent) ever leave the DI rolls.

DI benefits are subject to income and payroll taxation and replace approximately 70 percent of pre-disability net earnings up to a maximum of about €4,500 per month. The level of benefits is calculated by multiplying a pension coefficient, which varies by age and insurance years, with an assessment basis, which is the average indexed capped earnings over a given period of time (e.g., the best 16 years in 2004 at the beginning of our study period). Younger applicants with limited work experience qualify for a special increment to supplement their benefits. DI beneficiaries may continue work, but those earning more than an exempt threshold lose up to 50 percent of their benefits.[24] A pension reform in 2004 gradually decreased pension levels for most workers, providing exogenous variation in benefit levels to identify the labor market effects of changes benefit generosity (section 3.5).

[21] The insurance years requirement does not apply if the disability is job-related; for each occupation there exists an explicit list of qualifying impairments.

[22] To be classified as semi-skilled or skilled, an applicant must have worked in a semi-skilled or skilled occupation for 7.5 years or more in the most recent 15 years.

[23] Access to disability insurance is also relaxed in other countries at older ages, including Australia, Canada, Denmark, Sweden until 1997 (Karlström et al., 2008), and the United States (Chen and van der Klaauw, 2008).

[24] Ruh and Staubli (2016) show that this policy induces DI beneficiaries to keep their earnings below the exempt threshold in order to retain benefits.

In case of a temporary illness, employers continue to pay 100% of earnings for up to 12 weeks. Once the right to full benefits paid by the employer has expired, individuals may claim benefits from the Austrian SI system. SI benefits replace approximately 65% of the last net wage up to the same maximum that applies to DI benefits. Continued wage payments and SI benefits are both subject to income taxation. The benefit duration is 52 weeks for individuals who have worked at least 6 months in the previous 12 months, otherwise the duration is 26 weeks.

Regular UI benefits are a function of the wage on the last job and replace approximately 55 percent of the prior net wage subject to a minimum and maximum. The UI system is more generous for older workers. Specifically, while job losers below age 50 receive at most 39 weeks of regular UI benefits, job losers above age 50 can claim benefits for up to 52 weeks provided they have paid UI contributions for at least 9 years in the last 15 years. Job losers who exhaust the regular UI benefits can apply for "unemployment assistance" (UA). These means-tested transfers last for an indefinite period and are about 70 percent of regular UI benefits.

Data. We merge data from two administrative registers. First, the Austrian Social Security Database (ASSD) contains detailed longitudinal information for the universe of workers in Austria between 1972 and 2018. At the individual level the data include gender, nationality, month and year of birth, blue- or white-collar status, and labor market history. Labor histories are summarized in spells; all employment, unemployment, disability, sick leave, and retirement spells are recorded. Spells before 1972 are available for individuals who have claimed a public pension by the end of 2008. The ASSD also contains some firm-specific information: geographic region, industry affiliation, and firm identifiers that allow us to link both individuals and firms. See Zweimüller et al. (2009) for a detailed description of the data. Second, we use data on all DI applications, which cover the period 2004 to 2017 and contain detailed information on the date of the application, the date of the decision, the decision itself (i.e. reject or accept), the reported medical impairment of the applicant, and the stage of the application (i.e. first application, re-application, or appeal).

Starting from the population data set, we impose three restrictions. First, we exclude women because their eligibility age for an old age pension gradually increased from age 56 to age 60 during our observation window. Staubli and Zweimüller (2013) show that this increase had sizeable employment and unemployment effects. Second, we exclude self-employed and civil service workers, because they are covered by a different pension system than private-sector workers. Third, we exclude observations in which individuals are over age 62, at which point many individuals become eligible for an old age pension. Our sample covers more than three quarters of all active labor market participants in Austria. Since we can observe complete work histories, we can precisely calculate (1) how much DI benefits individuals would get at any point in time and (2) whether individuals have sufficient work experience to apply for DI benefits under the relaxed eligibility criteria above the RSA.

Table 3.1 shows summary statistics for the "screening sample", we use to study the effects of stricter disability screening. To capture changes in labor market behavior around the RSA, we limit the sample to men between age 54 and age 62 with at least 10 employment years in the past 15 years (measured at age 56). These men are considered eligible for relaxed screening, while men with less than 10 employment years in the past 15 years are considered ineligible.[25] We will use the sample of ineligibles for placebo tests. Since our empirical strategy exploits increases in the RSA from 57 to 58 and from 58 to 59, we distinguish between three cohorts of men: RSA 57, RSA 58, and RSA 59 who qualify for relaxed screening at age 57, age 58, and age 59, respectively. We observe individuals on a quarterly basis.

Our first set of outcome variables focus on DI application behavior. *Application ever* is an indicator for whether an individual has ever applied for DI benefits. *Application yearly* is an indicator for whether an individual has applied for DI benefits at a particular age. We also distin-

[25] Note that only individuals who worked in a *similar occupation* for 10 of the last 15 years are eligible for relaxed screening, while our definition is based on whether somebody has worked in *any occupation* for 10 years of the last 15 years because we can only observe industry affiliation and not occupation. This implies that the eligible sample will include some individuals who are in fact not eligible for relaxed screening, but this number is likely small because what constitutes a similar occupation is defined very broadly.

guish yearly applications by the underlying health impairment (mental disorders, musculoskeletal disorders, and other disorders) and whether the applications is a re-application, meaning that the applicant has applied for DI before. The second set of outcome variables focus on labor market outcomes. *DI benefit receip*t is an indicator for whether an individual is receiving DI benefits, *employment* is indicator for whether an individual is employed, and *other benefit receipt* is an indicator for whether the individual is receiving UI or SI benefits.[26] In the empirical analysis, we also calculate the benefit and earnings streams associated with each labor market status, allowing us to study the fiscal effects of stricter disability screening. Finally, we have some information on background characteristics, which we use to characterize individuals who, when screening becomes stricter, are on the margin of applying (marginal applicants) and on the margin of being awarded DI benefits (marginal enrollees).

Table 3.1: Summary statistics, screening sample

	RSA 57	RSA 58	RSA 59
Application ever (%)	17.23	14.83	11.84
Application yearly (%)	4.66	3.96	3.54
w/ mental disorders	0.65	0.63	0.60
w/ musculoskeletal system	2.24	1.78	1.51
w/ other disorders (%)	1.78	1.56	1.44
Re-application yearly (%)	1.46	1.41	1.28
DI benefit receipt (%)	12.94	10.01	7.01
Employment (%)	75.54	77.69	81.60
Other benefit receipt (%)	7.51	7.85	7.92
Avg. annual earnings (euro)	41,148	42,193	43,007
	(10,743)	(10,933)	(10,956)
Insurance years by age 50	28.72	29.29	29.44
	(7.02)	(6.97)	(6.78)
Employment years by age 50	13.87	13.93	13.95
	(2.01)	(1.99)	(1.99)
Was on sick leave (%)	33.27	32.02	31.15
No. Observations	1,557,723	887,252	809,342
No. Individuals	49,418	28,144	29,245

Notes: The table presents summary statistics of men between age 54 and age 62. The RSA 57 cohort are men born between December 1953 and November 1955, the RSA 58 cohort are men born between December 1955 and November 1956, and the RSA 59 cohort are men born between December 1956 and November 1957.

Table 3.2 shows summary statistics for the "benefit generosity sample", we use to study the effects of changes in DI benefit levels. Following Mullen and Staubli (2016), we define a reference date, January 1, and obtain all information to compute potential DI benefits and other relevant individuals characteristics as of this date for each year an individual is not receiving DI benefits. We estimate the effects separately for men who, on January 1, are 56-59 years old (they will reach the RSA within a year) and 30-55 years old. Our main outcome variables of interest are indicators for whether, within a year, individuals apply for DI (DI application yearly), are awarded DI benefits (DI inflow), exit employment (employment outflow), or stop receiving UI or SI benefits (other benefit outflow).

[26]DI spells are back-dated in the ASSD to the date the claim was filed, so an individual who applied for disability benefits late in the calendar year and was awarded benefits in the next calendar year is observed to claim disability benefits in the original calendar year.

Table 3.2: Summary statistics, benefit generosity sample

	Age Groups	
	56-59	30-55
DI application yearly (%)	6.23	0.41
w/ mental disorders	0.44	0.07
w/ musculoskeletal system	1.86	0.06
w/ other disorders	3.93	0.28
DI inflow (%)	4.34	0.19
Employment outlfow (%)	2.01	0.03
Other benefits outflow (%)	2.33	0.16
Age (years)	57.35	39.96
	(6.71)	(2.62)
Insurance years	37.03	20.37
	(8.11)	(7.01)
Tenure	6.92	5.25
	(6.04)	(5.02)
Last annual earnings (euro)	38,201	38,624
	(20,556)	(17,563)
Avg. annual earnings (euro)	37,216	42,472
	(13,775)	(13,796)
No. Observations	1,575,659	12,989,251
No. Individuals	215,348	1,421,953

Notes: Table presents summary statistics of men in our benefit generosity sample.

3.4 Impacts of Stricter Disability Screening

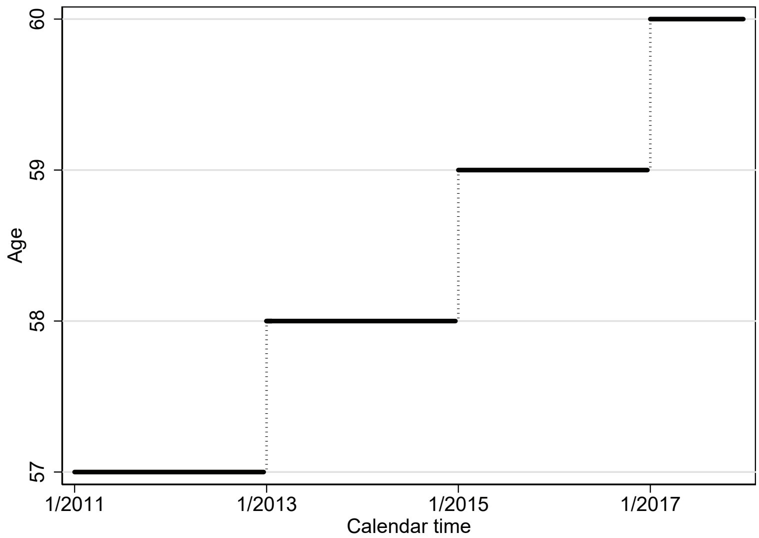
3.4.1 The 2013 reform

In April 2012, the Austrian government announced the 2. Stability Act (2. Stabilitätsgesetz), which became effective on January 1, 2013. The Act had two primary objectives: reduce expenditures in the public pension systems and foster employment among older workers. The only change to the DI program was a step wise increase in the RSA threshold from age 57 to age 60. As Figure 3.5 shows, the RSA was increased to age 58 in January 2013, followed by further increases to age 59 in January 2015 and age 60 in January 2017. Individuals who had not worked in a similar occupation for 10 years in the last 15 years were not affected by the increases as they were not eligible for relaxed screening. We focus on the 2013 and 2015 changes, because the available data preclude the analysis of the 2017 change.

The RSA increases create variation in disability screening stringency at certain ages across birth cohorts. For example, the RSA is 58 for men who turn 57 in December 2012 or after (those born after November 1955).[27] We label this birth cohort the RSA 58 cohort. Conversely, the RSA is 58 for men born before December 1955 and we label this cohort the RSA 57 cohort. Men in the RSA 58 cohort, compared to men in the RSA 57 cohort, face stricter disability screening at age 57. The RSA is 59 for men born after November 1956 and we therefore label this cohort the RSA 59 cohort. Men in the RSA 59 cohort, compared to men in the RSA 57 cohort, face stricter screening at ages 57 and 58.

[27] Applications are assessed using the rules in the month after filing. Therefore, if someone turns 57 in December 2012 and applies to DI his application is evaluated in January 2013, when the new RSA 58 applies.

Figure 3.5: Increase in the RSA



Notes: This figure displays the stepwise increase in the relaxed screening age (RSA) for DI benefits from age 57 to age 60, as mandated by the 2012 2nd Stability Act.
Source: Austrian federal law (Bundesgesetzblatt) no. 35/2012.

Figure 3.6 provides descriptive evidence on the labor market effects of the RSA increases. We plot the percent of 54 to 61 year old men receiving DI benefits, having ever applied for DI, working, and receiving other benefits by birth cohort. For each variable, trends across birth cohorts are remarkably similar until age 57 – the relaxed screening age for the RSA 57 cohort. At this age, the DI recipient rate rises sharply in the RSA 57 cohort. The percent of DI applicants also increases, suggesting that individuals are aware of the RSA and time their DI application to this age. Conversely, the percent of men in the RSA 57 cohort who are employed or receive other benefits drops at age 57, pointing to the role of DI as a substitute for UI or SI.

We observe similar breaks in trends when the RSA 58 and RSA 59 cohorts reach their RSA, but interestingly cohorts with a higher RSA never catch up to cohorts with a lower RSA. For example, the DI recipiency rate rises sharply at age 58 for the RSA 58 cohort, but it never reaches the level of the RSA 57 cohort. A one year increase in the RSA changes labor market dynamics not only at the age where disability screening becomes stricter, but also at higher ages. Our empirical strategy is designed to separately identify the effect of the RSA at the ages where screening becomes stricter as well as at higher ages where screening is relaxed.

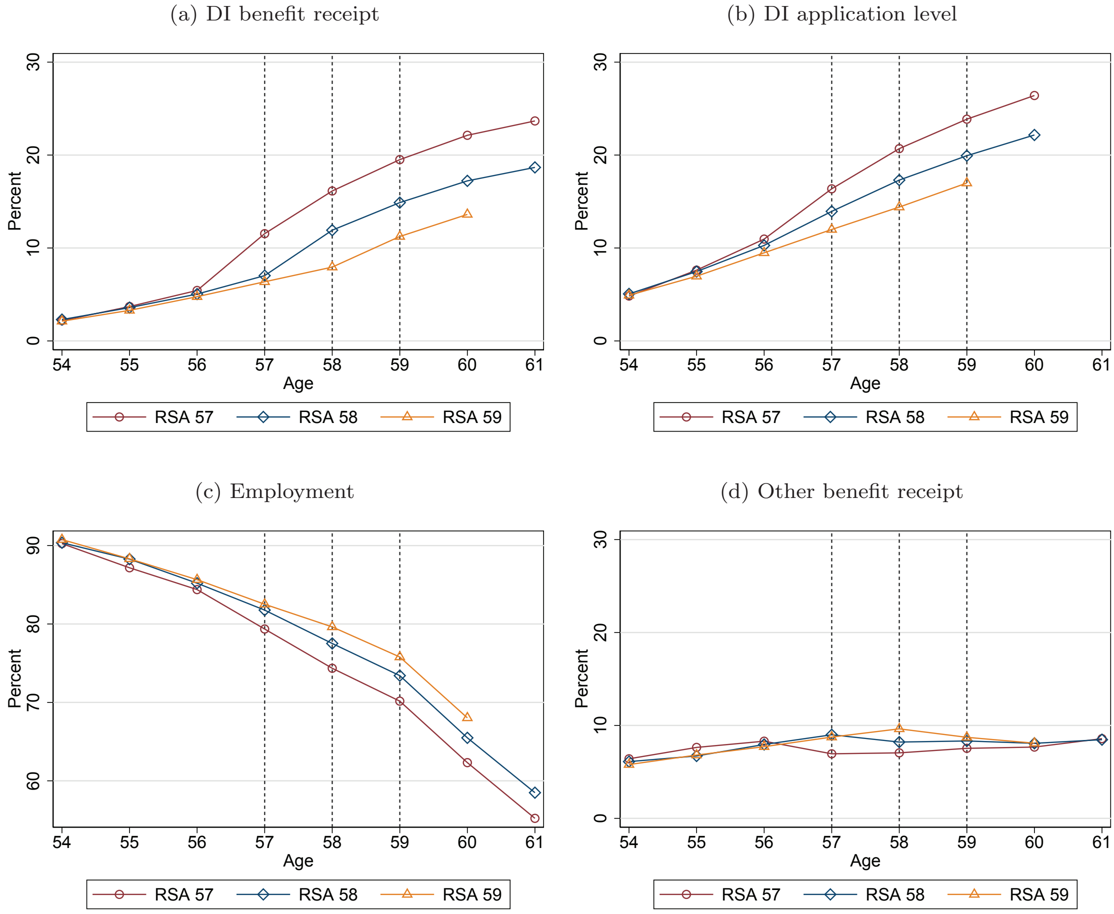
3.4.2 Estimation Strategy

Our estimation strategy exploits the exogenous variation in the RSA threshold across birth cohorts using a difference-in-differences design. Older birth cohorts are eligible for relaxed screening already at age 57, while younger birth cohorts only become eligible at age 58 or age 59. Thus, we can identify the effect of stricter screening by comparing the age profiles of younger and older birth cohorts. This comparison can be implemented by estimating regressions of the following type:

$$y_{it} = \alpha + \theta_a + \pi_c + \lambda_t + \sum_{k=54\backslash 56}^{61} \beta_k I[age = k] + X_{it}'\delta + \varepsilon_{it}, \tag{3.15}$$

where i denotes individual, t year-quarter, c birth cohort; y_{ict} is the outcome variable of interest (such as an indicator for having ever applied for DI, an indicator for receiving DI benefits, and

Figure 3.6: Labor market states and DI applications by age and RSA for men



Notes: The figure shows trends in DI receipt, DI application levels (measuring whether somebody has ever applied for DI), employment, and other benefit receipt by age and RSA.

labor supply measures such an indicator for working), θ_a are dummies for age in years to control for age-specific levels in the outcome variable, π_c are dummies for year-month of birth to capture time-constant differences across birth cohorts, λ_t are dummies for year and quarter to capture common time shocks and seasonal effects, and X_{ict} represent individual or region specific characteristics to control for any observable differences that might confound the analysis. We cluster standard errors at the year-month of birth.

The key variables of interest are the indicators $I[age = k]$, which are equal to one if an individual's age is equal to k, where k runs from 54 to 61 using $k = 56$ as the reference age. Each β_k-coefficient measures the average causal effect of an RSA increase at age k. To obtain the average effect of an RSA increase over a wider age interval, we can simply take the average of different β_k-coefficients. For example, $\sum_{k=57}^{61} \beta_k/5$ measures the average change in the outcome variable at each age in the age interval 57 to 61.

We estimate the effects of the RSA 58 and RSA 59 change separately, using always the RSA 57 cohort as the control group. This way we can compare whether an increase in the RSA by one year (from 57 to 58) has similar effects as an increase in the RSA by two years (from 57 to 59). Another reason to estimate the effects separately is that, compared to the RSA 58 cohort, men in the RSA 59 cohort have more time to adjust to the reform. They just turned 55 years old when the reform was announced, while men in the RSA 58 cohort were almost 57 years old. Having more time to adjust increases the scope for anticipation effect: changes in behavior even before age 57.

The identification assumption is that, absent the increase in the RSA, the change in y_{it} at a certain age would have been comparable between birth cohorts who are eligible for relaxed screening and those not yet eligible. A potential concern is that age-specific trends in the outcome variable could be changing across birth cohorts for reasons unrelated to the RSA increases. The estimated β_k-coefficients for $k < 57$ provide placebo checks for spurious trends. They should not be statistically significant if the identification assumption hold, although they could also pick up anticipation effects. As an additional placebo check, we estimate equation (3.15) for men who at age 56 have worked less than 10 years in the past 15 years and are therefor not eligible for relaxed DI screening. They should not respond to the changes in the RSA.

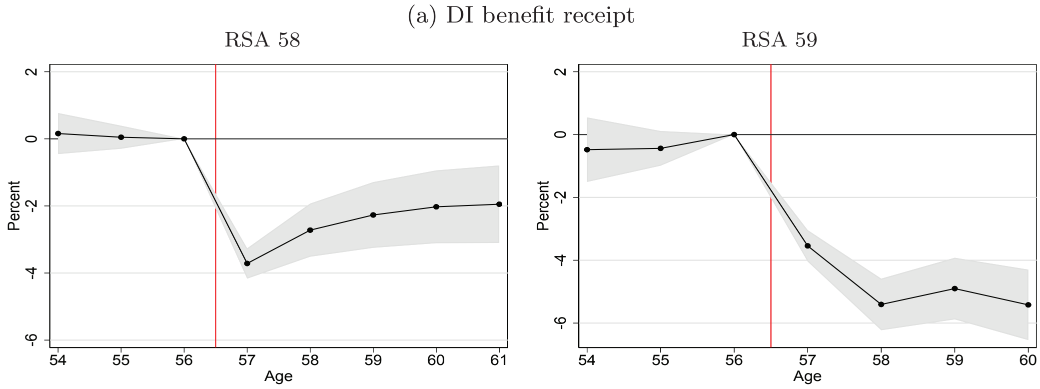
3.4.3 Main Results

Figure 3.7 shows the estimated β_k-coefficients from equation (3.15) for the RSA 58 and the RSA 59 increases for four key outcomes. The shaded area denotes the 95 percent confidence interval. In all graphs, we see that the estimates before age 57, the pre-reform RSA, are close to zero and statistically insignificant, providing evidence that the estimates are not confounded by differential trends across birth cohorts.

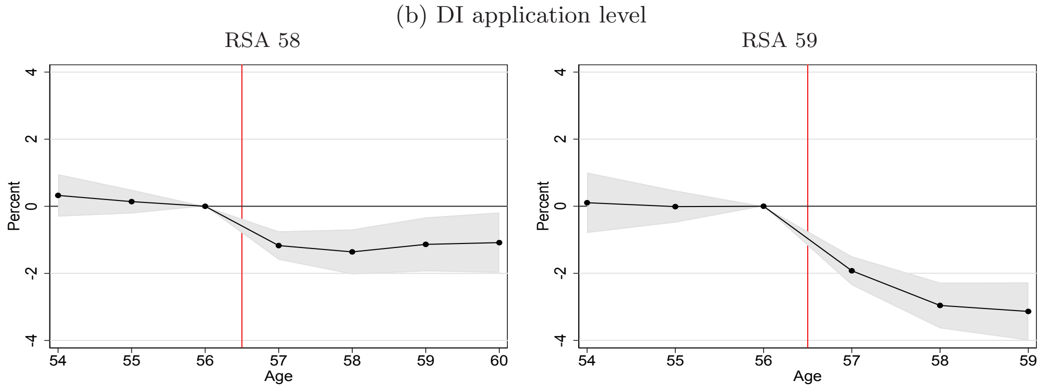
As panel (a) shows, because of the increases in the RSA, fewer men receive DI benefits between age 57 and age 61. At age 57, DI recipiency rates drop by about 4 percentage points for the RSA 58 and RSA 59 cohorts relative to the RSA 57 cohort. For the RSA 58 cohort, DI recipiency rate remains lower after age 57, even though disability screening is now relaxed. For the RSA 59 cohort, the DI recipiency rate declines further at age 58, because they only qualify for relaxed screening at age 59, but even at age 59 (and age 60) the DI recipiency rate remains lower.

Figure 3.7: Effects of RSA on labor market states and DI applications by age

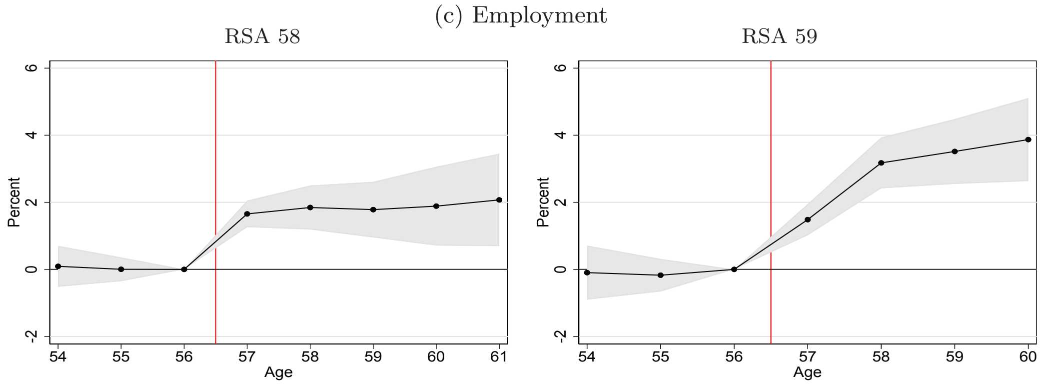
(a) DI benefit receipt



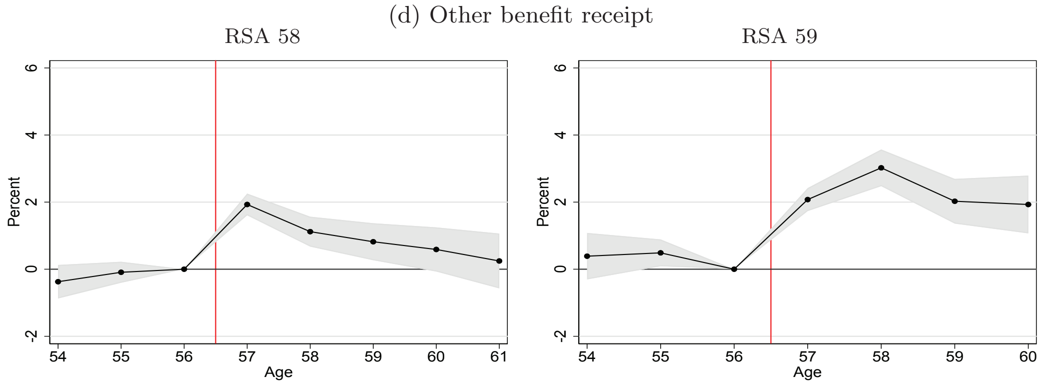
(b) DI application level



(c) Employment



(d) Other benefit receipt



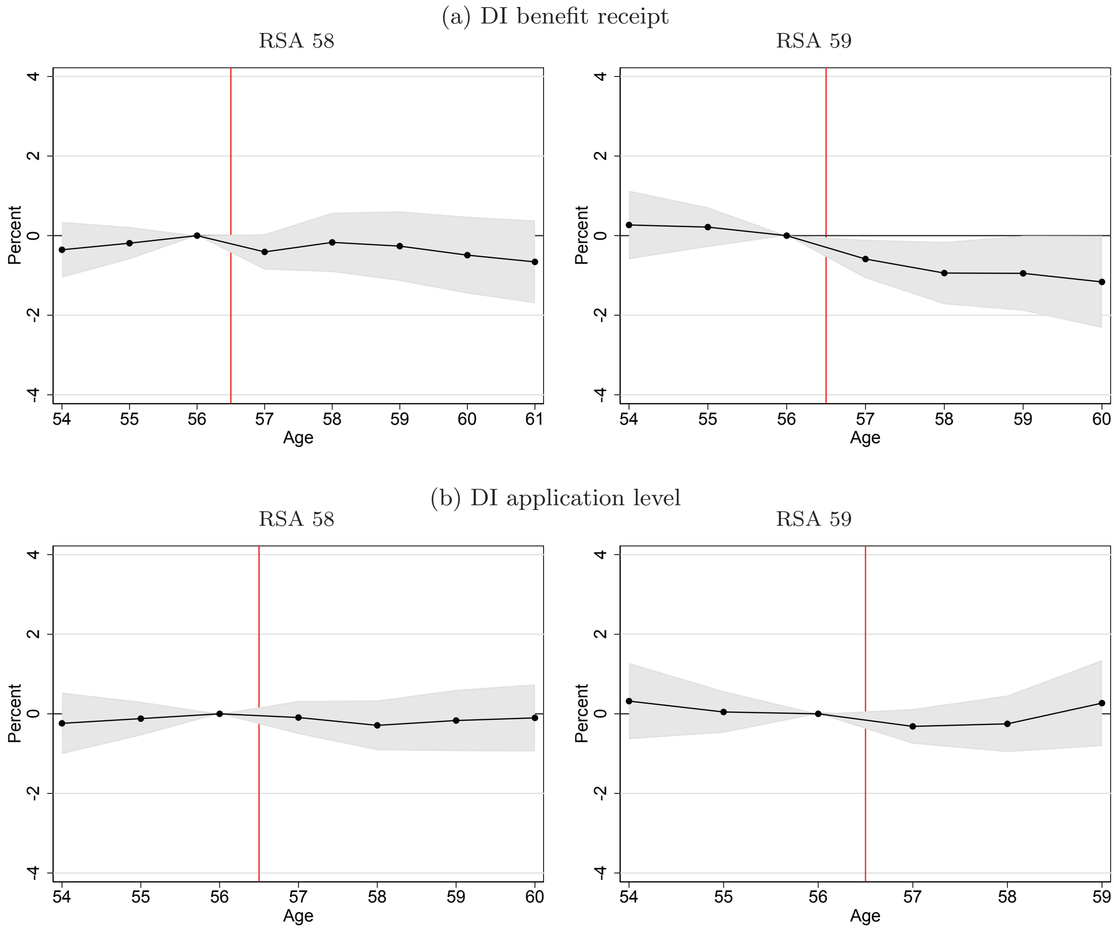
Notes: The figure shows the estimated β_k-coefficients from equation (3.15) for the RSA 58 and the RSA 59 increases for four key outcomes. The shaded area denotes the 95 percent confidence interval.

Panel (b) documents that fewer men in the RSA 58 and RSA 59 cohorts apply for DI benefits after age 56, particularly for the RSA 59 cohort. A drop in applications provides evidence consistent with applications for DI being costly. Paying the application cost becomes less attractive once disability screening becomes stricter. For the RSA 58 cohort, we observe that the decline in application rates persists even after they become eligible for relaxed screening. For the RSA 59 cohort, we cannot examine application rates after they reach their RSA, because our data end at age 59.

Panels (c) and (d) shows that stricter disability screening increases employment and other benefit receipt above age 56 for the RSA 58 and RSA 59 cohorts. The expansion in employment persists until the last age, where we can observe these cohorts, and is about twice as large for the RSA 59 cohort compared to the RSA 58 cohort. The rise in other benefit receipt is temporary for the RSA 58 cohort and vanishes completely after age 59, while it persists up to the last age for the RSA 59 cohort.

The timing and dynamics of these estimates directly relate to the discussion of the dynamic effects in the model from Section 3.2.2 in three ways. First, we find no evidence for forward-looking anticipation effects (changes in behavior before age 57). For the RSA 58 cohort this is not surprising because they learned about the reform just a couple months before they turn 57. However, the RSA 59 cohort knew about the reform 2 years before turning 57 and had time to adjust. Nevertheless, all estimates before age 57 are close to zero and insignificant. Second, DI applications fall at age 57 implying that individuals are aware of this policy and adjust their behavior. If the estimated effects were purely mechanical, the applications should no react at age 57. Third, it is interesting how persistent the effects are. DI levels are permanently lower by around 2 pp and employment rates are 2 pp higher for the RSA 58 cohort. The question is whether this is due to permanent changes in behavior or the persistence of the mechanical effect. Section 3.6 will shed light on this by estimating the mechanical effect directly.

Figure 3.8: Effects of RSA on DI benefit receipt and DI applications by age, non-eligibles



Notes: The figure shows the estimated β_k-coefficients from equation (3.15) for the RSA 58 and the RSA 59 increases for individuals not affected by the policy change because they have too little work experience to qualify for relaxed screening. Finding no significant effects for ineligible men provides strong support that our main estimates are not confounded by differential trends across birth cohorts.

In Figure 3.8, we plot the estimated β_k-coefficients from equation (3.15) for men with too little work experience to be eligible for relaxed screening. We find that DI benefit recipiency and DI applications do not differ significantly across birth cohorts, even after age 56. As Appendix Figure 3.12 shows, we also find that employment and other benefit do not differ across birth cohorts. Finding no significant effects for ineligible men provides strong support that our main estimates are not confounded by differential trends across birth cohorts.

A useful way to summarize the effects of stricter screening is by taking the average of the β_k-coefficients after age 56 (since point estimates are insignificant before age 57). We report these estimates in Table 3.3 for the RSA 58 and RSA 59 increases, distinguishing between men who are and are not eligible for relaxed screening. The estimates capture the average effect between age 57 and age 61 for the RSA 58 increase and between age 57 and age 60 for the RSA 59 increase.[28]

[28]While the effects are still visible at age 61 for RSA 58 and age 60 for RSA 59, these effects should disappear at age 62 when most men in Austria retire (see Figure 3.13 in the Appendix). We can estimate the effect of RSA 58 and RSA 59 up to age 62 if we assume that the RSA increases have the same effect until age 62 as at the last age, we currently observe in the data. This assumption is reasonable because the effects stabilize after age 58 as Figure 3.7 shows. Appendix Table 3.8 shows the corresponding average effects up to age 62. They are statistically indistinguishable from the estimates in Table 3.3.

Table 3.3: Average effect of stricter screening

	Eligible				Non-eligible			
	2013		2015		2013		2015	
	Estimate	Mean	Estimate	Mean	Estimate	Mean	Estimate	Mean
A. Labor market effects (%)								
DI benefit receipt	-2.54***	18.56	-4.82***	17.3	-0.40	38.17	-0.91**	37.52
	(0.44)		(0.41)		(0.38)		(0.39)	
Application ever	-1.19***	21.81	-2.67***	20.29	-0.16	38.61	-0.1	37.89
	(0.34)		(0.32)		(0.32)		(0.34)	
Employment	1.85***	68.36	3.01***	71.59	0.32	14.34	0.2	14.73
	(0.39)		(0.39)		(0.3)		(0.33)	
Other benefit receipt	0.94***	7.55	2.26***	7.30	-0.01	19.8	0.49	20.08
	(0.25)		(0.27)		(0.38)		(0.39)	
B. Fiscal effects (euro)								
DI benefits	-884***	6756	-1727***	6245	-115	11012	-395***	10721
(A)	(161)		(150)		(120)		(113)	
Tax revenue	263***	11185	407***	11625	16	1582	-10	1608
(B)	(56)		(59)		(33)		(35)	
Other benefits	172***	1217	448***	1182	-5	2233	89	2277
(C)	(46)		(57)		(55)		(62)	
Total fiscal effect	-976***	-3213	-1686***	-4199	-135	11663	-297***	11389
(A-B+C)	(185)		(176)		(115)		(113)	
No. Observations	2,444,975		2,176,311		916,207		806,100	

Notes: Tabe presents average effect of the RSA for the ages above the RSA. The estimates are constructed by summing up all the β_k-coefficients from equation 3.15 for $k \geq 57$ and dividing by the number of years above the RSA.

The exception are DI applications, which we can only track up to age 60 for the RSA 58 increase and up to age 59 for the RSA 59 increase.

Concerning the labor market effects (Panel A), we find that the share of men in the RSA 58 cohort receiving DI benefits declines by 2.54 percentage points, or about 14 percent relative to the mean above the RSA. Men in the RSA 58 cohort are also less likely to apply for DI, but the decline is only half as large as the decline in DI benefit receipt. Most men in the RSA 58 cohort who are screened out of the DI program continue to work: the average employment rate increases by 1.85 percentage points. But benefit substitution is also important: other benefit receipt increases by 0.94 percentage points. The RSA 59 cohort experiences similar changes in labor market outcomes as the RSA 58 cohort, but the effects are about twice as large. The larger effects for the RSA 59 cohort makes sense, because their RSA increases by two years as opposed to one year. On the other hand, we find that men who are not eligible for relaxed screening barely change their labor market behavior. The DI recipiency rate declines among non-eligible men in the RSA 59 cohort, but the reduction is about five times smaller compared to eligible men and likely reflects that some non-eligible men become eligible for relaxed screening as they get older.

Panel B reports the fiscal effect of RSA 58 and RSA 59 increases. Theses estimates are crucial for assessing the welfare effects of stricter screening. We focus on four outcomes: DI benefits, tax revenue, other benefits, and the total fiscal effect, which is simply the sum of benefits received minus taxes paid. We calculate these outcomes on an individual basis, multiplying at each age the number of days an individual spends in a given labor market state times the daily benefit received or taxes paid in that state. We then estimate equation (3.15) for each outcome separately and average the β_k-coefficients above age 56. Appendix Figure 3.15 plots the estimated β_k-coefficients. They are close to zero and statistically insignificant before age 57, while they are statistically different from zero after age 56.

We find that the stricter screening lessens spending on DI benefits and raises tax revenue from increased work activity, but also raises spending on other benefits because of benefit substitution. The reduction in DI benefits for RSA 58 is 884 euro per individual, which in absolute value is about three times larger than the increase in tax revenue (263 euro) and five times larger than the increase in other benefits (172 euro). Overall, we find that the total fiscal cost at each age above 56 declines by 976 euro per individuals. For the RSA 59 increase, we find that the estimates are about twice as large among men eligible for relaxed screening, while they are small and mostly insignificant for men not eligible for relaxed screening.

3.4.4 Complier Analysis

In this section, we apply the complier analysis method for difference-in-differences settings to study the characteristics of marginal applicants and enrollees whose behavior is affected by stricter screening (Imbens and Rubin (1997); Abadie (2003); Jäger et al. (2019)). We compare the average of a specific characteristic, for example average earnings at age 56, among individuals who apply or enroll when screening is relaxed to those who apply or enroll when screening is strict. The differences in the average characteristics uncover how marginal applicants or enrollees who apply or enroll only when screening is relaxed differ from always applicants or enrollees who apply or enroll even when screening is strict. We can also compare average characteristics of marginal applicants or enrollees to those of never applicants or enrollees who do not apply or enroll even when screening is relaxed.[29]

Table 3.4 shows the population shares and average characteristics of marginal applicants and enrollees, always applicants and enrollees, and never applicants and enrollees for the RSA 58. Appendix Table 3.10 shows analogous results for the RSA 59 change; they resemble qualitatively the results for the RSA 58 change. Marginal applicants are less likely to be on sick leave at age 56 than always applicants, but more likely than never applicants. Whether somebody is on sick leave or not is a good proxy for the underlying health status. Marginal applicants also have less labor market attachment than never applicants, but more than always applicants. For example, 73 percent of marginal applicants are employed at age 56, compared to 60 percents of always applicants and 87 percent of never applicants. Compared to always and never applicants, marginal applicants are also more likely to be blue-collar workers, consistent with low-skilled workers experiencing the largest relaxation in disability screening. They are more likely to apply with a musculoskeletal impairment, consistent with the RSA targeting older workers.

We see similar patterns when comparing marginal enrollees to always and never enrollees. Marginal enrollees are more likely to work in blue-collar jobs and to apply with a musculoskeletal impairment. They are also in better health, as proxied by sick leave at age 56, than always enrollees, but in worse health than never enrollees. To better understand who is screened out when screening becomes stricter, we can compare characteristics of marginal enrollees and marginal applicants.[30] This comparison reveals that marginal enrollees have less labor market attachment, have lower earnings, and are less healthy than marginal applicants, implying that stricter screening screens out marginal applicants whose work capacity is likely higher.

3.5 Impact of Benefit Generosity

The ideal experiment to analyze the impact of a change benefit generosity would be to randomize the level of DI benefits across individuals. We emulate this ideal experiment with a

[29] Appendix 3.C provides a detailed discussion of how we implement the complier analysis in our setting.

[30] Appendix Figures 3.20 and 3.21 graphically illustrate differences between marginal applicants and enrollees as well as between always applicants and enrollees.

Table 3.4: Applicant and enrollee characteristics, RSA 58

	Marginal (M)	Always (A)	Difference M-A	Never	Difference M-N
A. Applicants					
Share in population	1.44***	7.00***	-5.56***	91.56***	-90.13***
	(0.13)	(0.11)	(0.22)	(0.06)	(0.17)
Sick Leave at age 56 (%)	1.00	9.63***	-8.63***	1.03***	-0.03
	(1.87)	(0.30)	(2.11)	(0.02)	(1.87)
Unemployed at age 56 (%)	21.02***	26.02***	-5.00	4.91***	16.11***
	(3.38)	(0.59)	(3.89)	(0.04)	(3.38)
Employed at age 56 (%)	72.94***	60.29***	12.65***	86.57***	-13.64***
	(3.85)	(0.65)	(4.39)	(0.07)	(3.85)
Avg. annual earnings (euro)	41,183***	40,894***	289	46,074***	-4,891***
	(791)	(146)	(918)	(27)	(792)
Blue-collar (%)	93.26***	81.35***	11.91***	55.29***	37.98***
	(3.59)	(0.63)	(4.12)	(0.12)	(3.60)
Musculoskeletal (%)	59.52***	43.89***	15.63***		
	(4.57)	(0.77)	(5.23)		
Mental (%)	15.27***	14.28***	0.99		
	(3.44)	(0.64)	(4.02)		
Other (%)	25.21***	41.83***	-16.62***		
	(4.66)	(0.77)	(5.33)		
B. Enrollees					
Share in population	3.84***	1.67***	2.16***	94.49***	-90.65***
	(0.07)	(0.05)	(0.12)	(0.05)	(0.11)
Sick Leave at age 56 (%)	10.78***	15.9***	-5.18***	1.01***	9.77***
	(0.40)	(0.63)	(0.92)	(0.01)	(0.40)
Unemployed at age 56 (%)	36.13***	23.05***	13.07***	5.13***	31.00***
	(0.71)	(0.88)	(1.39)	(0.04)	(0.71)
Employed at age 56 (%)	49.41***	57.37***	-7.96***	86.44***	-37.03***
	(0.74)	(0.99)	(1.54)	(0.07)	(0.74)
Avg. annual earnings (euro)	40,639***	41,433***	-794*	45,919***	-5,280***
	(177)	(321)	(467)	(25)	(179)
Blue-collar (%)	88.12***	77.20***	10.91***	56.07***	32.04***
	(0.81)	(1.40)	(2.07)	(0.11)	(0.81)
Musculoskeletal (%)	56.40***	28.83***	27.57***		
	(0.98)	(1.43)	(2.17)		
Mental (%)	6.96***	23.46***	-16.50***		
	(0.78)	(1.47)	(2.14)		
Other (%)	35.43***	46.26***	-10.83***		
	(1.02)	(1.69)	(2.53)		

Notes: Tabe presents the population shares and average characteristics of marginal applicants and enrollees, always applicants and enrollees, and never applicants and enrollees for the RSA 58.

quasi-experimental research design that exploits variation in DI benefits from a large pension reform. Our approach follows Mullen and Staubli (2016) who estimate the elasticity of DI claiming with respect to benefit generosity using variation in DI benefits in Austria from several reforms between 1987 and 2010. We differ from their study in two aspects: First, we update their estimates for a more recent time period (2004 to 2017). This period is characterized by lower replacement rates and stricter disability screening compared to the 1980s and 1990s, which could affect the responsiveness of DI claiming and applications to benefit levels. Second, we study the effect of benefit generosity on a novel set of outcomes, including employment, other benefit receipt, and fiscal costs, which are key for assessing the welfare effects of a change in benefit generosity.

3.5.1 The 2003 Pension Reform

In January 2004, the Austrian government implemented several changes to the calculation of DI benefits as part of a larger reform (Pensionsreform 2003). These changes reduced the potential benefit level for most individuals, although individuals with limited work history experienced an increase in the potential benefit level. Before the reform they qualified for a special supplement to their benefits if they were below age 56. The reform gradually increased the age limit for the special supplement to age 60 between 2004 and 2010. Over the same time, the reform phased in a reduction in the pension coefficient and an increase in the penalty for claiming benefits before the normal retirement age (age 65 for men and age 60 for women).[31] The reform also gradually increased the length of the assessment basis from 16 years to 40 years by 2028. The large scale reduction in benefits was heavily criticized by the public. In response to the backlash, the Austrian government passed legislation in 2005, limiting the maximum benefit reduction to five percent of the projected pre-reform benefits. The maximum benefit reduction was then increased by 0.25 percent each year; in 2017 it was equal to 8.25 percent of pre-reform benefits.

3.5.2 Estimation Strategy

In this section, we describe how we isolate the variation in benefit levels stemming from the 2003 pension reform to estimate the causal effect of benefit generosity. We are interested in estimating the following regression:

$$y_{it} = \alpha + X'_{it}\beta + \gamma b_{it}(Z_{it}) + \lambda_t + \varepsilon_{it}, \tag{3.16}$$

where i denotes individual, t year, y_{it} is the outcome variable of interest such as applying for DI, X_{it} is a vector of demographic and labor market characteristics, $b_t(Z_{it})$ are log potential DI benefits which are a function of labor market characteristics $Z_{it} \in X_{it}$ (e.g. age, insurance years, and the assessment basis), λ_t are year fixed effects, and ε_{it} are any unobserved factors affecting the outcome such as taste for work. The parameter of interest is γ which measures the average effect of a change in benefit levels on the outcome variable.

As Mullen and Staubli (2016) discuss, if b is a linear function of Z_{it}, we cannot separately identify γ and β because no variation is left in b after controlling for Z_{it}. If γ is a non-linear function of Z_{it}, we can identify γ as long as sufficient residual variation is left in b after controlling for Z_{it}.[32] A drawback of this identification strategy is that it relies heavily on functional form (Bound (1989)) . This problem can be solved by exploiting the 2003 reform because it creates variation in b that is independent from Z_{it}. Intuitively, with the policy reform we observe individuals with similar Z_{it} but different benefits b. This approach is akin to a difference-in-differences estimation strategy,

[31] Before the reform each insurance year increased the pension coefficient by 2 percentage points, while each year of claiming before the full retirement age reduced the pension coefficient by 3 percentage points (capped at a maximum of 10.5 percentage points or 15 percent of the pre-penalty pension coefficient, whichever is lower). The reform gradually reduced the pension coefficient adjustment for each insurance year from 2 to 1.78 percentage points between 2004 and 2009 and changed the penalty for each year of early claiming to 4.2 percent of the pension coefficient (capped at 15 percent of the full pension).

[32] For example, if we control for Z_{it} in a very flexible way by including polynomials or other transformations of Z_{it},γ may not be identified because potential benefits are collinear with Z_{it}.

where identification is obtained by relating individuals' differential response to their differential change in benefit levels stemming from the policy reform.[33]

Mullen and Staubli (2016) show that the policy-induced variation in b can be isolated by including the individual-specific (log) hypothetical benefits under each policy regime as additional controls in equation (3.16). Due to the phased-in nature of the 2004 policy reform, we have 14 different hypothetical benefits for each year from 2004 to 2017:

$$y_{it} = \alpha + X_{it}'\beta + \gamma b_{it}(Z_{it}) + \sum_{r=2}^{14} \delta_r b_r(Z_{it}) + \lambda_t + \varepsilon_{it}, \tag{3.17}$$

where $b_r(Z_{it})$ denotes hypothetical DI benefits under the policy regime r. By controlling for hypothetical DI benefits, we guarantee that actual potential benefits are uncorrelated with any unobservable factors affecting the outcome variable, so that γ identifies the causal effect of DI benefits. We cluster standard errors at the year-month of birth.

3.5.3 Empirical Results

Our main results are summarized in Table 3.5 with Panel A providing estimates of equation (3.17) for labor market outcomes and Panel B displaying analogous estimates for fiscal outcomes, which serve as inputs for the fiscal multiplier. Panel A indicates that an increase in benefit levels increases the propensity of applying for DI benefits. The additional DI inflow comes from outflow of other welfare benefits and we find no employment effect. For the age group 30-55 the effects are much smaller in absolute size but disability is also much less prevalent in this age group. In relative terms, we find comparable effects. For the age group 30-55 the inflow effect is around one third of the application effect, while it is around one half for the age group 56-59. This is likely driven by the higher award rates for 56-59 agegroup because of the RSA at 57. Panel B shows the corresponding fiscal effects.

3.6 Estimating the Fiscal Multiplier of DI Reforms

The purpose of this section is to estimate the quantitative magnitude of the fiscal multiplier resulting from DI policy reforms. As we argued above, this is of crucial interest. The fiscal multiplier gives us a critical benchmark for welfare analysis. If a DI reform (that tightens DI eligibility rules or cuts DI benefits) generates a fiscal multiplier of 2, then taking away one dollar from DI recipients (absent any behavioral responses) needs to generate an insurance loss of more than 2 dollars to make the reform welfare-reducing. That is, one dollar in the hands of affected DI recipients must have a social value of at least 2 dollars. In the following we estimate the fiscal multiplier of stricter screening and reducing benefit generosity.

Fiscal Multiplier of Increasing RSA. Increasing the RSA by one year, from age 57 to 58, corresponds to increasing the strictness of screening at age 57. To assess the welfare effect of this policy change we need to implement inequality (3.13) and therefore identify the fiscal multiplier (lhs) and the loss in insurance value (rhs). We focus here on the fiscal multiplier and discuss in Appendix 3.D how we can put an number on the insurance value. For the fiscal multiplier we need to decompose the fiscal cost effect into the mechanical and behavioral fiscal effect. For this decomposition our strategy is to estimate the mechanical fiscal effect and then back out the behavioral fiscal effect as the residual of the total fiscal cost effect, which we estimated in Section 3.4, and the mechanical fiscal effect.

[33] This approach has been used by Fevang et al. (2017) to estimate the effect of temporary disability insurance benefits on the duration of temporary disability insurance spells using policy variation in Norway and Nielsen et al. (2010) to estimate the response of college enrollment to changes in student aid using a Danish reform.

Table 3.5: Average effect of benefit generosity

	Ages 56-59		Ages 30-55	
	Estimate	Mean	Estimate	Mean
A. Labor market effects (%)				
DI application	0.171***	26.71	0.014***	1.66
	(0.019)		(0.003)	
DI inflow	0.093***	18.68	0.003***	1.22
	(0.015)		(0.001)	
Employment outflow	-0.004	71.43	<0.001	89.24
	(0.011)		(0.001)	
Other benefits outflow	0.097***	9.89	0.003***	9.54
	(0.012)		(0.001)	
B. Fiscal effects (euro)				
DI benefits	36.95***	4,516	2.26***	324
(A)	(3.16)		(0.26)	
Payroll taxes	-2.37***	9,915	-0.19***	10,322
(B)	(1.12)		(0.07)	
Other benefits	-20.62***	1,944	-1.27***	1,630
(C)	(2.33)		(0.24)	
Behavioral fiscal effect	18.69***	-3,455	1.18***	-8,368
(D=A-B+C)	(3.14)		(0.18)	
Observations	1,453,448		15,968,003	

Notes: This Table presents the estimates of regression (3.17).

Estimating the mechanical fiscal effect of stricter screening is not straightforward. As we discussed in Section 3.2.2, the mechanical fiscal effect spreads over multiple periods and depends on the mechanical change in the award rate and the labor market behavior of rejected individuals. These are two counterfactuals we do not directly observe empirically. Theoretically, the mechanical fiscal effect is driven by always applicants.[34] If we could directly classify individuals as always-, marginal and never applicants, we would be able to apply our difference-in-difference strategy in the subgroup of always applicants and directly identify the fiscal effect in this group $\mathbb{E}[\Delta G|\text{always applicants}]$. Rescaling this effect by the share of always applicants π^{AA}, which we estimated in Section 3.4, yields the mechanical fiscal effect in the population $\mathbb{E}[M(\theta^*_{57})] = \pi^{AA}\mathbb{E}[\Delta G|\text{always applicants}]$.[35] However, we cannot directly classify individuals as always-, marginal and never applicants.[36] Therefore, we construct a counterfactual group for the always applicants and apply our difference-in-difference strategy in this counterfactual group. Our counterfactual group for the always applicants are individuals who apply to DI between age 50 and 56. In this age window both treatment and control cohorts face the strict screening standard and hence are always applicants at that age. We refer to this group as the counterfactual always applicants. Some of these counterfactual always applicants get on DI, some are rejected and reapply at age 57. At age 57, the treatment cohort is still under the strict regime while the control cohort faces the lenient standard which allows us to estimate the fiscal cost effect in this subgroup. We use the same approach to estimate the mechanical effect of the RSA 59 change.

The key question is whether this subgroup provides a good counterfactual for the always applicants. We think this is the case for two main reasons. First, always applicants should not change their application behavior in response to stricter screening at age 57. Figure 3.9 plots the difference-in-difference estimates for DI applications and DI inflow for the counterfactual always applicants. Panel (a) shows that there is no application response in our counterfactual group at age 57. At age 58 there is an increased number of applications because at age 57 more applicants are rejected, as shown by the DI inflow effect in Panel (b), and the rejected applicants reapply at age 58. For the RSA 58 cohort there is an increase in DI inflow, because more individuals apply and screening is again lenient. For the RSA 59 group, the strong increase in DI inflow is at age 59 when they again face the lenient rules. Hence, the application and DI inflow patterns of the counterfactual always applicants look exactly as one would expect for always applicants. Second, we can directly compare the outcomes after the application at age 57 of the counterfactual always applicants to the always applicants. Applicants at age 57 under the strict rules are always applicants (Hence, applicants at age 57 in the treatment cohort are always applicants). In Figure 3.10 panel (a) and (b) we compare DI benefit receipt and net fiscal expenditures of always applicants (those from the treatment cohort who apply at age 57 for the first time, blue line) to the counterfactual always applicants (those from the treatment cohort who applied already between age 50-56 and reapply at age 57, red line). After date 0, the application date at age 57, DI benefit receipt and net fiscal expenditures of the two groups are very similar and 3 quarters after the application the two lines are not statistically significantly different. Before date 0 the counterfactual always applicants and always applicants show very different patterns. This is natural as the counterfactual always applicants already applied to DI before date 0 while the always applicants have not. Figure 3.10 therefore shows that under the strict rules our counterfactual

[34] We make the explicit link between always applicants and the mechanical fiscal effect in the discussion of non-marginal changes in Appendix 3.B.1 and 3.B.2.

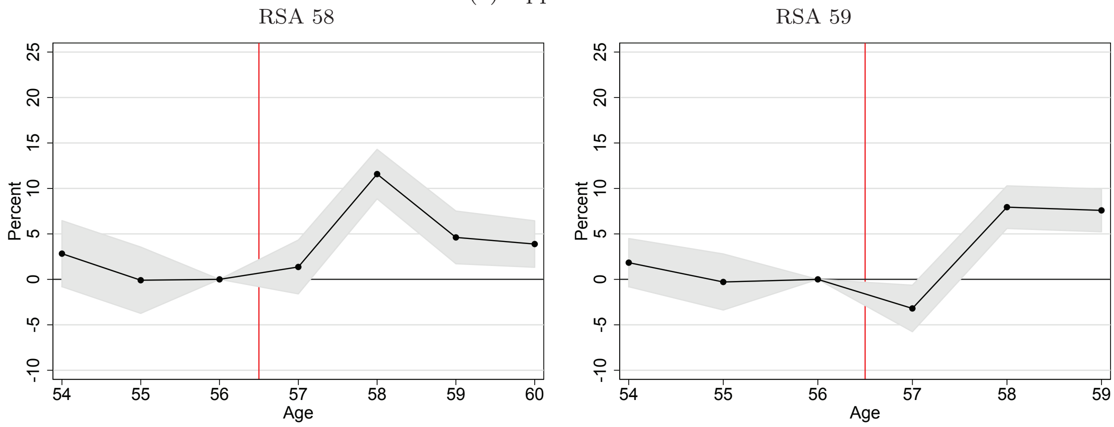
[35] In the model's notation: The estimate of the fiscal effect in the group of always applicants is $\mathbb{E}[\Delta G|\text{always applicants}] = \mathbb{E}\left[G(P^H) - G(P^L)|\alpha^H_{i,s} = 1\right] = \frac{1}{\pi^{AA}}\mathbb{E}\left[\sum_{t=s}^{T-1}(1+r_t)^{-t}\left(M_{\Delta W_{i,t}}(b_{i,t}+\tau_{i,t}) + M_{\Delta Z_{i,t}}(b_{i,t}-z_{i,t})\right)\right]$ where $\pi^{AA} = \mathbb{E}\left[\alpha^H_{i,s}\cdot\prod_{k=0}^{s-1}\left(1-\alpha^H_{i,k}p_{i,k}\right)\right]$ and $s = 57$. Hence, the mechanical fiscal effect is $\mathbb{E}[M(\theta^*_s)] = \pi^{AA}\mathbb{E}\left[G(P^H) - G(P^L)|\alpha^H_{i,s} = 1\right]$

[36] DI applicants at age 57 in the treatment group are always applicants as they face the strict rules. The applicants at age 57 in the control group are a mix of always and marginal applicants. Based on this we can determine the share of marginal and always applicants and their pre-treatment characteristics as in Section 3.4. We cannot directly characterize how treatment (stricter screening) affects outcomes within these groups because treatment affects the composition of treatment and control group as well as their (labor market) outcomes.

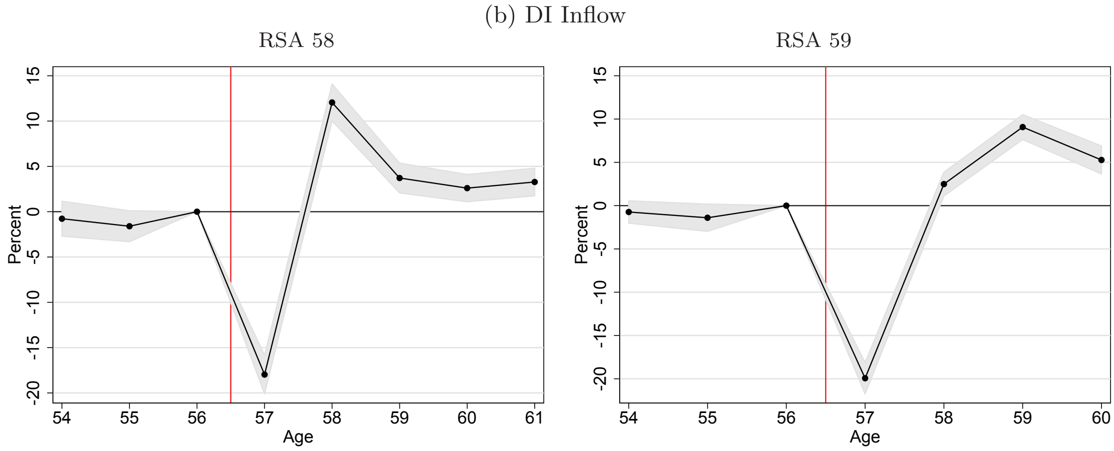
group shows the same patterns as the always applicants after an application at age 57. This is reassuring that our counterfactual group provides a good approximation of always applicants.

Figure 3.9: DI application and inflow effects for always applicants

(a) Applications



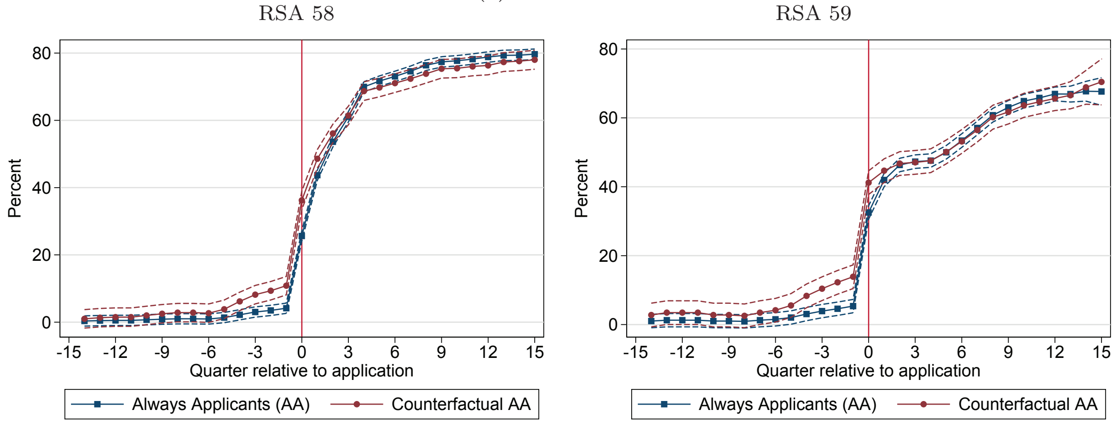
(b) DI Inflow



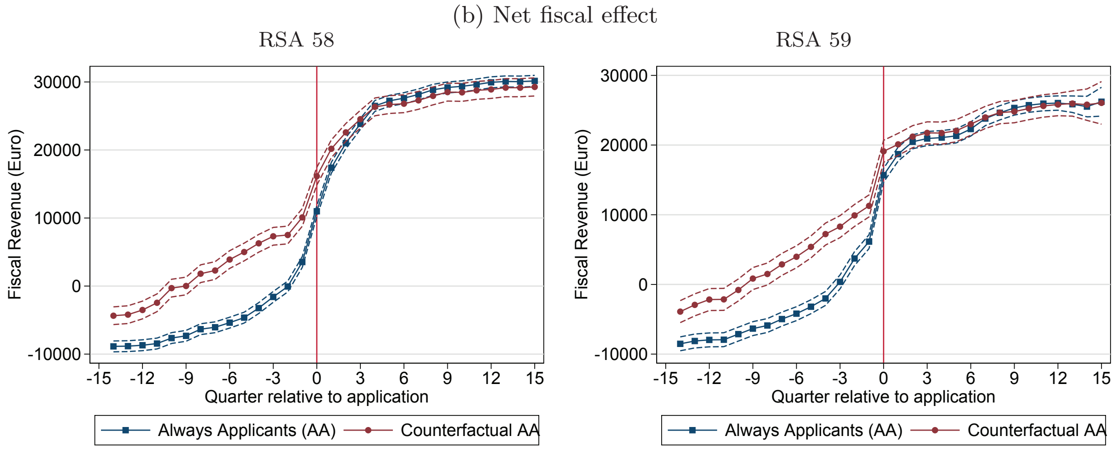
Notes: The figure shows the estimated β_k-coefficients from equation (3.15) for the RSA 58 and the RSA 59 counterfactual group of always applicants for DI applications and DI inflow.

Figure 3.10: Comparison of Always Applicants (AA) and Counterfactual AA

(a) DI benefits



(b) Net fiscal effect

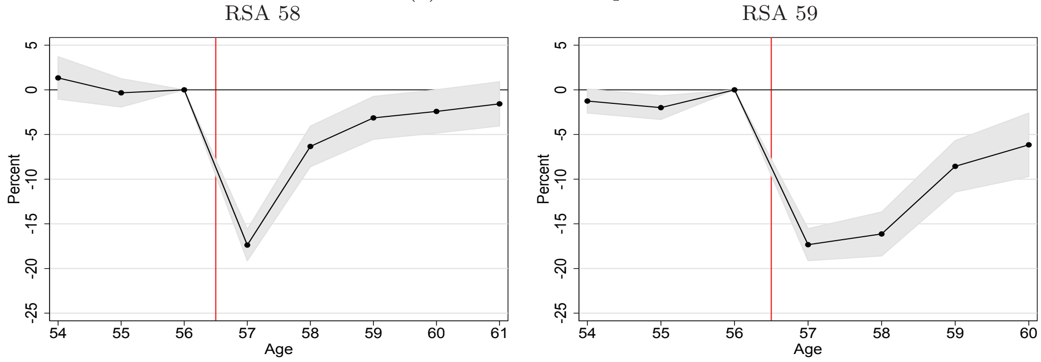


Notes: The figure compares the counterfactual always applicants (red line) to the always applicants (blue line) in the treatment group. The overlap of the two lines after an application at age 57 (date 0) suggests that the counterfactual always applicants are indeed comparable in outcomes to always applicants.

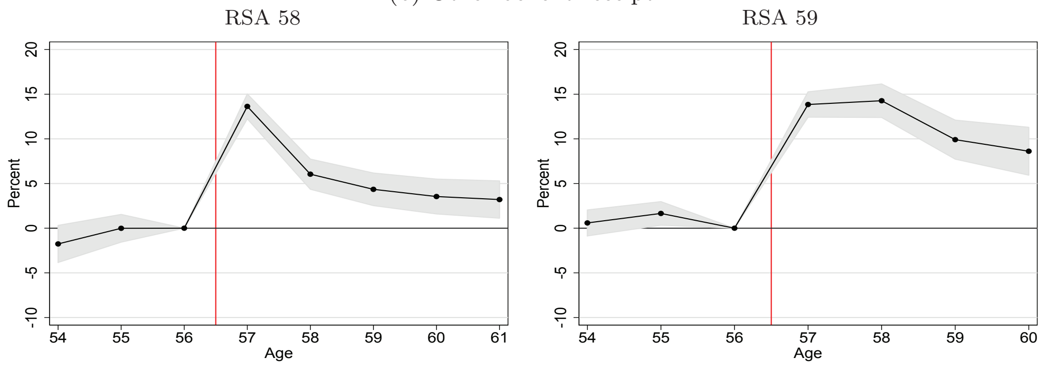
Within this group of counterfactual always applicants we exploit the difference-in-difference strategy from section 3.4. Figure 3.11 plots the difference-in-difference estimates by age for labor market outcomes and the net fiscal effect. Figure 3.11 provides empirical evidence on the persistence of the mechanical effect (as theoretically discussed in Section 3.2.2). For the RSA 58 cohort, DI benefit receipt significantly drops at age 57 and then steadily catches up and is at age 59/60 back to the level of the cohort with lenient screening at age 57. Interestingly, the always applicants have a small employment effect at age 57 that vanishes afterwards. Most individuals substitute to other welfare benefits. This implies that the permanent changes in employment and disability receipt in the population in Figure 3.7 must be driven by behavioral changes and are not due to a persistent mechanical effect. We see similar patterns for the RSA 59 cohort. There the mechanical effect persists for 2 years and then starts to disappear, exactly as one would expect.

Figure 3.11: Mechanical effects of RSA on labor market states and fiscal revenue

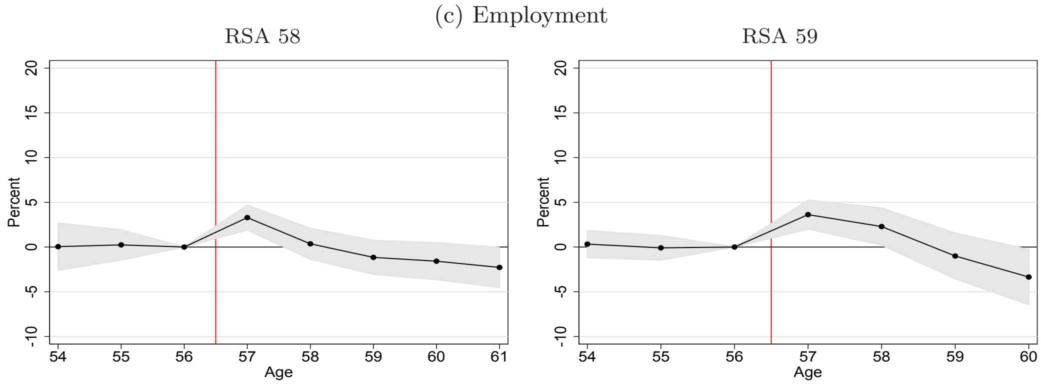
(a) DI benefit receipt



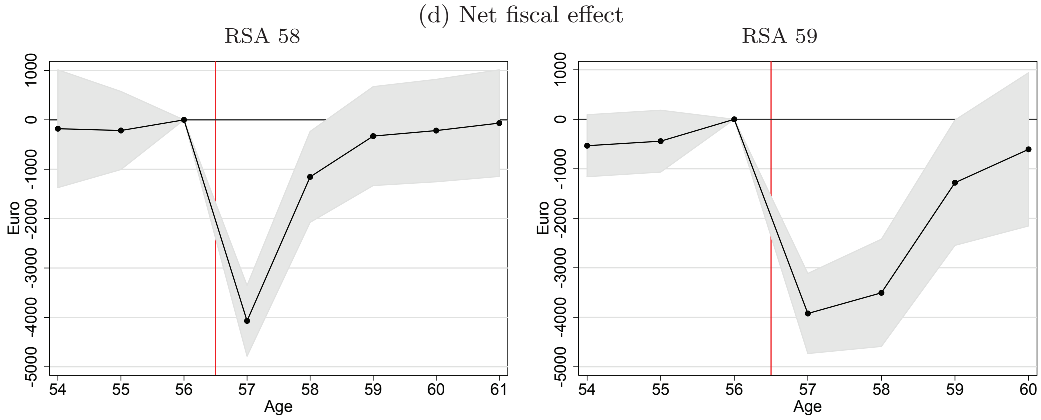
(b) Other benefit receipt



(c) Employment



(d) Net fiscal effect



Notes: The figure shows the estimated β_k-coefficients from equation (3.15) for the RSA 58 and the RSA 59 increases for the counterfactual always applicants.

Table 3.6: Fiscal multiplier for screening

	2013		2015	
	Estimate	Percent	Estimate	Percent
Total fiscal effect	976		1,686	
Mechanical fiscal effect (M)	391	40%	823	49%
Behavioral fiscal effect (B)	585	60%	863	51%
Fiscal multiplier (1+B/M)	2.50		2.05	

Notes: Tabe presents average effect of the RSA for the ages above the RSA and decomposes the total fiscal effect into the behavioral and mechanical fiscal effect.

Table 3.6 presents the decomposition of the fiscal effect into behavioral and mechanical fiscal effect. Table 3.6 shows that for a one year increase in the RSA the net fiscal effect of always applicants is $\mathbb{E}[\Delta G|\text{always applicants}]$ =5,585 Euro.[37] Multiplying this by the share of always applicants from Table 3.4, $\pi^{AA} = 0.07$, yields the mechanical fiscal effect of 391 Euros. The behavioral fiscal effect is calculated as the difference between the fiscal cost effect from Table 3.3, 976 Euros, and the mechanical fiscal effect. This decomposition implies a fiscal multiplier of 2.5. For the two year increase in the RSA from 57 to 59 we find a multiplier of 2.05.

The multiplier has to be compared to the insurance value to assess the welfare effect of the reform. The insurance value measures the social value of one dollar in the hands of the mechanically screened out DI applicants. Hence, increasing the RSA by one year (two years) is welfare increasing if 1 dollar in the hands of affected DI recipients has a social value of less than 2.5 dollars (2.05 dollars). The fiscal multiplier therefore is the evaluation benchmark for the insurance value. The major empirical innovation of this paper is to shed light on the fiscal multiplier of stricter screening. Nevertheless, we also discuss in Appendix 3.D how we can put a number on the insurance value. Using bounds and assuming CRRA utility we find that increasing the RSA by one or two years is welfare improving if risk aversion is below 2.

Fiscal Multiplier of Reducing Benefit Generosity. In section 3.5, we estimate the behavioral fiscal effect of increasing benefit generosity by one percent for different age windows (Table 3.5). To determine the fiscal multiplier in Table 3.7 we additionally need the mechanical fiscal effect. For changes in benefit levels it is straightforward to calculate the mechanical fiscal effect. The mechanical fiscal effect of a one percent reduction in DI benefits is simply one percent of the pre-reform mean of DI benefit expenditures ($0.01 \cdot 4,516 = 45.16$ for 56-59 year olds and $0.01 \cdot 324 = 3.24$ for 30-55 year olds). The total fiscal effect in Table 3.7 is then the sum of behavioral and mechanical fiscal effect. For reducing the benefit generosity we find fiscal multipliers of 1.41 and 1.36 for the age groups 56-59 and 30-55 respectively. For welfare evaluation the fiscal multiplier has again to be compared against the insurance value. In Appendix 3.D we provide an approach to estimate the insurance value. With this approach we find that DI benefits are optimal for values of risk aversion around 1.

Screening vs. Benefit. The fiscal multiplier of stricter screening are sginificantly larger than the fiscal multipliers of reducing DI benefits. For each mechanical one dollar reduction, stricter screening at age 57 generates 1.1 dollar more cost savings (fiscal multiplier of screening = 2.5; fiscal multiplier of benefit generosity = 1.41). This implies that by increasing strictness of screening the

[37] This effect is constructed as follows. We estimate the the net fiscal effect within our counterfactual group $\mathbb{E}[\Delta G|\text{counterfactual always applicants}]$. We estimate $\mathbb{E}[\Delta G|\text{counterfactual always applicants}]$=1167 Euro. This effect is driven by individuals who reapply at age 57 and not all counterfactual always applicants reapply at age 57. For the fiscal effect of always applicants we therefore rescale by the probability to reapply at age 57: $P(\text{reapply at 57}) = 0.209$. This delivers $\mathbb{E}[\Delta G|\text{always applicants}] = \frac{1}{P(\text{reapply at 57})}\mathbb{E}[\Delta G|\text{counterfactual always applicants}] = 5585$ in Table 3.6.

Table 3.7: Fiscal multiplier for benefit generosity

	Ages 56-59		Ages 30-55	
	Estimate	Percent	Estimate	Percent
Total fiscal effect	-63.85		-4.42	
Mechanical fiscal effect (M)	-45.16	71%	-3.24	73%
Behavioral fiscal effect (B)	-18.69	29%	-1.18	27%
Fiscal multiplier (1+B/M)	1.41		1.36	

Notes: Tabe presents the decomposition of the fiscal cost effect of a benefit reduction into the behavioral and mechanical fiscal effect.

policy maker can induce larger behavioral changes and generate greater cost reductions compared to reducing DI benefits. Hence, on the cost side stricter screening is more effective. The key question for the relative comparison is how the insurance values of the two policy instruments compare. It could be that reducing benefit generosity creates a much lower insurance loss than stricter screening. If the insurance loss of reducing benefits was more than 1.1 dollars smaller, then reducing benefits would still be prefereable to stricter screening despite the much lower multiplier. The insurance loss is to some degree speculative and requires more structure and assumptions. Our implementation in Appendix 3.D suggests that the insurance loss of stricter screening is not substantially larger than the insurance loss of reducing benefit generosity and therefore stricter screening is preferable.

Comparison to DI in the United States. The U.S. DI eligibility criteria are also subject to vocational factors similar to the RSA in Austria. This medical-vocational grid introduces sharp discontinuities in initial award rates by age. Chen and van der Klaauw (2008) use these discontinuities to estimate the labor supply effects of DI benefit receipt. We use their estimates for our sufficient statistics formula to discuss the welfare effects of abolishing/shifting these age cutoffs in the U.S. We find that in the U.S. abolishing/shifting these age cutoffs would be welfare reducing.

In contrast to Austria the U.S. age cutoffs do not seem to affect application behavior. There is no strategic bunching of applications at these ages, see Figure 6 in Chen and van der Klaauw (2008). Chen and van der Klaauw (2008) argue that these rules are not well-known among DI applicants and therefore there is no systematic sorting around the age cutoffs. This has two implications. First, in absence of systematic selection around the age cutoffs, the RDD in Chen and van der Klaauw (2008) is valid. Second, this suggests no behavioral response with respect to these age cutoffs, i.e. we might expect $B = 0$. Therefore, making screening stricter at these age cutoffs is welfare reducing if one dollar in the hands of DI recipients has a social value of at least one dollar. This is the case if we think that a DI recipient is at least as deserving as the average tax payer. Put differently, screening at ages below 55 is too strict.

To test the optimality of the benefit generosity we need an estimate of the DI take-up elasticity wrt. benefits. According to Low and Pistaferri (2015) (Table 7) empirical estimates of the application benefit elasticity range from 0.2 to 1.3. Low and Pistaferri (2015)'s model implies an application benefit elasticity of 0.62. For our sufficient-statistics formula we need the take-up elasticity. To obtain an upper bound of the take-up elasticity we multiply the application elasticity with the average award rate. This gives an upper bounds since the individuals who actually react to the benefits should have lower than average award rates. According to French and Song (2014) the award rate after 10 years from the initial application is 0.67. Hence, we get a take-up elasticity $\xi = 0.41$ and a fiscal multiplier of 1.41. Hence, with this back of the envelope calculation we find a similar fiscal multiplier in the U.S. as in Austria. The DI replacement rates in the U.S. are lower than in Austria and hence the insurance value in the U.S. should be higher than in Austria. This implies that benefits in the U.S. might to be too low. Our findings are in line with the conclusions in Low and Pistaferri (2015). They conduct the same policy experiments, that we study with our sufficient-statistics model, in their structural model. They (i) change the generosity of DI benefits and (ii) make screening stricter. While they study the effects for the full population in a life-cycle model, our analysis focuses on the local effect at age 55. Nevertheless, we reach the same conclusions. Low and Pistaferri (2015) find that reforms, which increase benefit generosity or relax screening stringency, are welfare improving.

3.7 Conclusion

In this paper, we provide a framework to analyze the welfare effects of stricter DI eligibility criteria versus lower DI benefits by developing sufficient-statistics formulas. We show that the fiscal multiplier is crucial for evaluation of the effectiveness of DI policies and estimate fiscal multipliers of stricter screening and lower DI benefits in the context of Austria.

To estimate the effects of stricter disability screening, we exploit variation in DI eligibility strictness that is generated by a policy reform. Prior to 2013 DI eligibility standards were significantly relaxed for workers above age 57 relative to those below age 57. A 2013 pension reform increased the relaxed screening age (RSA) threshold from age 57 to age 58, followed by further increases to age 59 in 2015 and age 60 in 2017. These step-wise increases generate quasi-experimental variation in the strictness of DI eligibility at a certain age by date of birth. To examine the impacts of changes in DI benefit levels, we exploit a large pension reform that reduced potential benefit levels for most individuals, although pension levels increased for some individuals with limited work experience.

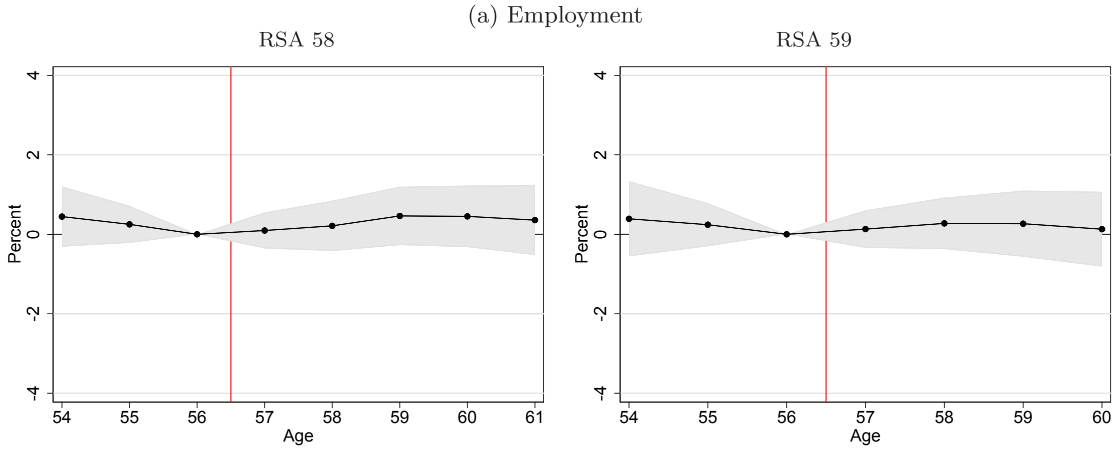
We find that stricter screening creates fiscal multipliers of 2-2.5 and reducing benefit generosity has fiscal multipliers of 1.3-1.4. This implies that by increasing strictness of screening the policy maker can induce larger behavioral changes and generate greater cost reductions compared to reducing DI benefits. Hence, on the cost side stricter screening is more effective. Reducing benefit generosity is only preferable to stricter screening if the insurance loss of reducing benefits was more than 1.1 dollars smaller than the insurance loss of stricter screening.

3.A Additional Tables and Figures

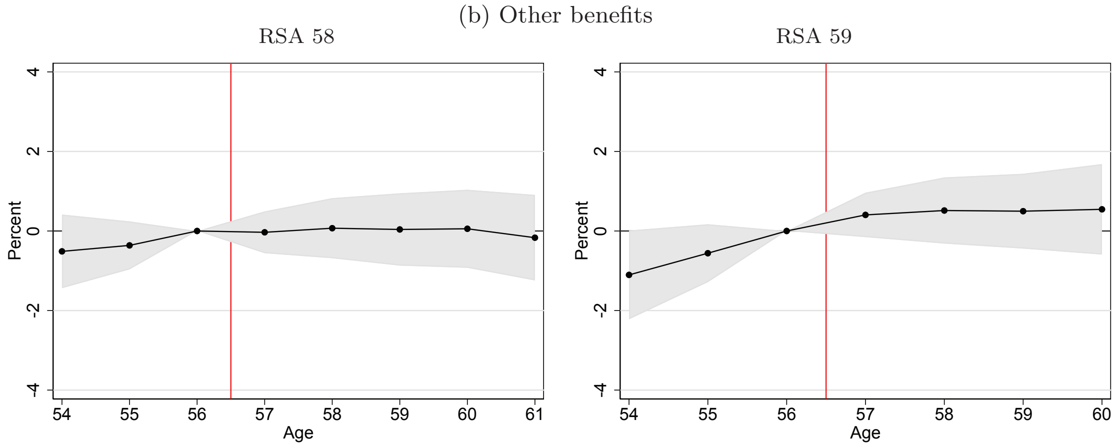
3.A.1 Effect on employment and other benefits among non-eligible men

Figure 3.12: Placebo employment and other benefit estimates using non-eligible men

(a) Employment



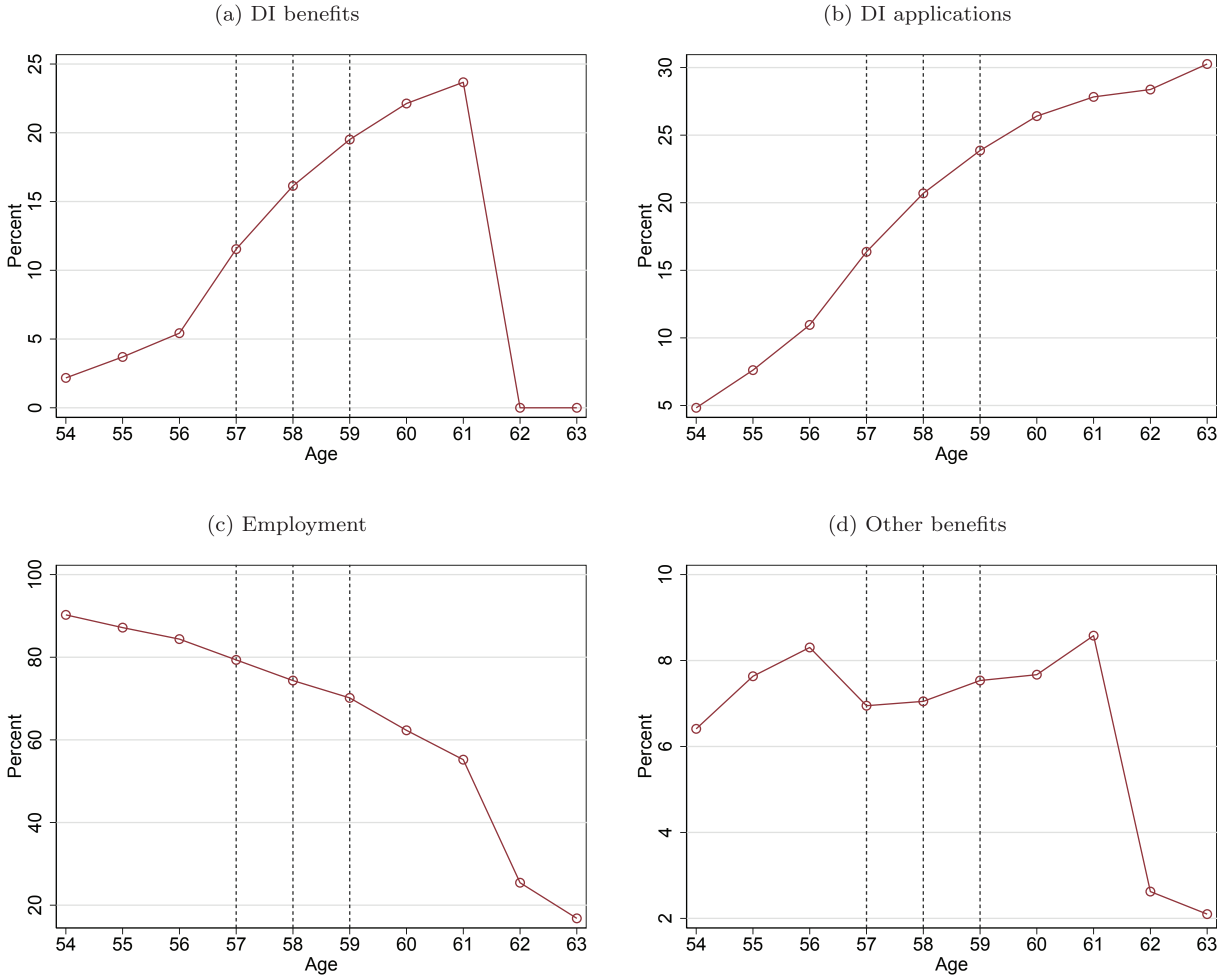
(b) Other benefits



3.A.2 Extending the effects up to age 62

The empirical results suggest that the RSA increases have long-term effect up to the last age, we can observe treated cohorts in the data (age 61 for the RSA 58 cohort and age 60 for the RSA 59 cohort). A natural question is whether these effects would continue even beyond the last age, we currently observe in the data? A simple way to shed light on this question is by looking at an older cohort, men born in 1954, who we can track until age 63. We would expect that the effects of the RSA increases disappear at age 62. At this age most men in Austria retire, because they become eligible for retirement benefits. Indeed, if we plot age trends in labor market outcomes and DI applications for men born in 1954 (Figure 3.13), at age 62 we observe sharp drops in the precent of men receiving DI benefits, being employed, or receiving other benefits.

Figure 3.13: Trends by age for eligible men born in 1954



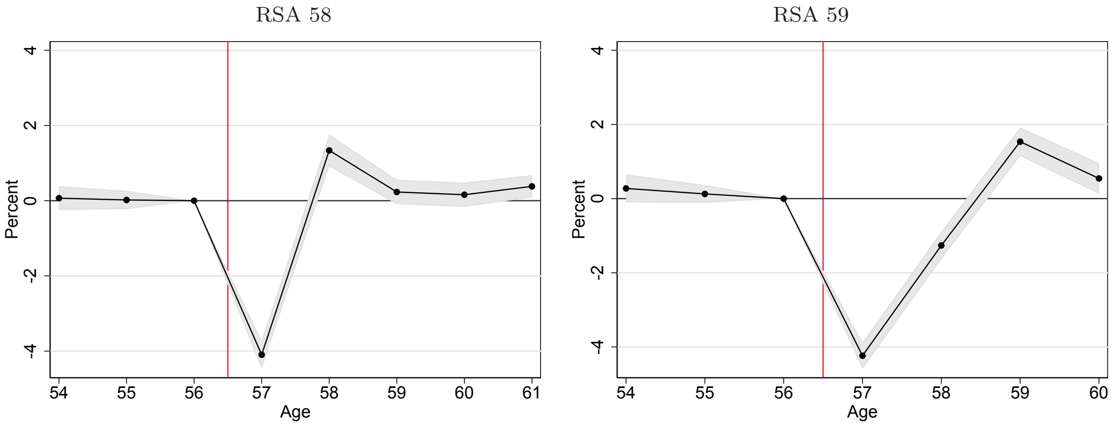
We can estimate the effect of the RSA increases up to age 62 if we assume that the β_k-coefficient estimates in equation (3.15) are unchanged between the last age, we currently observe in the data, and age 62. This assumption is reasonable because, as Figure 3.15 shows, the effects stabilize after age 58. Table 3.8 reports the correpsonding average effects between age 57 and age 61, that is $\sum_{k=57}^{61} \beta_k/5$. For the RSA 58 cohort, we can observe labor market outcomes up to age 61. Thus, the only estimate that changes compared to Table 3.3 is the estimate on DI applications, which we observe only until age 60. We find that the application rate declines by 1.17 percentage points on average, which is almost identical to the estimate in Table 3.3 (-1.19 percentage points). We find equally small differences when comparing the estimates for the RSA 59 cohort.

Table 3.8: Average effect above RSA up to age 61, men

	Eligible				Non-eligible			
	2013		2015		2013		2015	
	Estimate	Mean	Estimate	Mean	Estimate	Mean	Estimate	Mean
A. Labor market effects (%)								
DI	-2.54***	18.56	-4.94***	17.3	-0.4	38.17	-0.96**	37.52
	(0.44)		(0.43)		(0.38)		(0.42)	
Application ever	-1.17***	21.81	-2.86***	20.29	-0.15	38.61	0.05	37.89
	(0.36)		(0.36)		(0.34)		(0.42)	
Employment	1.85***	68.36	3.18***	71.59	0.32	14.34	0.19	14.73
	(0.39)		(0.43)		(0.3)		(0.35)	
Other	0.94***	7.55	2.20***	7.3	-0.01	19.8	0.5	20.08
	(0.25)		(0.30)		(0.38)		(0.42)	
B. Fiscal effects (euro)								
DI benefits	-884***	6756	-1793***	6245	-115	11012	-445***	10721
(A)	(161)		(159)		(120)		(123)	
Tax revenue	263***	11185	427***	11625	16	1582	-16	1608
(B)	(56)		(65)		(33)		(38)	
Other benefits	172***	1217	451***	1182	-5	2233	92	2277
(C)	(46)		(63)		(55)		(67)	
Net fiscal cost	-976***	-3213	-1769***	-4199	-135	11663	-338***	11389
(A-B+C)	(185)		(186)		(115)		(123)	
No. Observations	2,444,975		2,176,311		916,207		806,100	

3.A.3 Effect on disability inflow

Figure 3.14: Effect on disability inflow



3.A.4 Fiscal effects

Figure 3.15: Fiscal effects of RSA increase by age

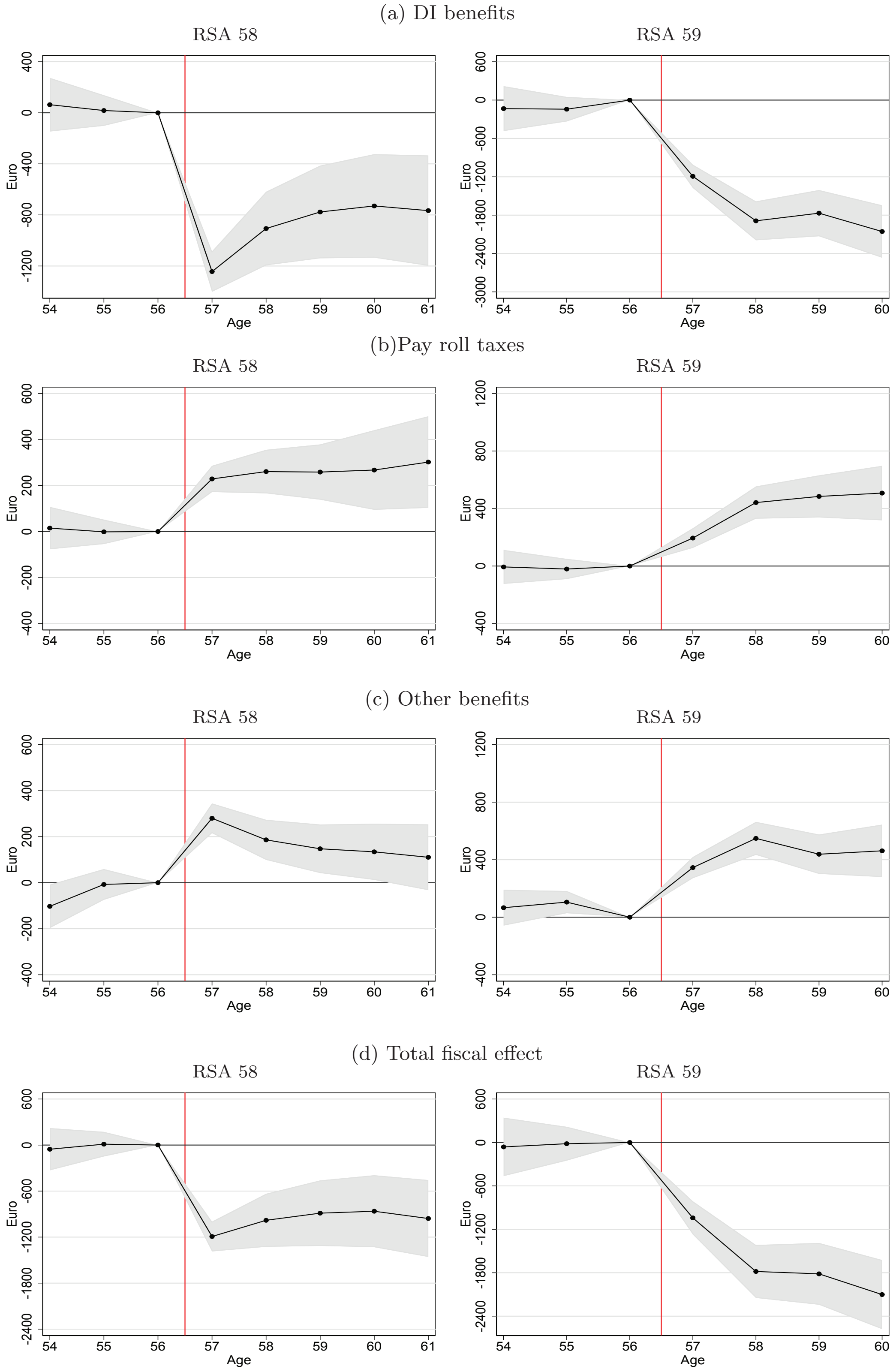
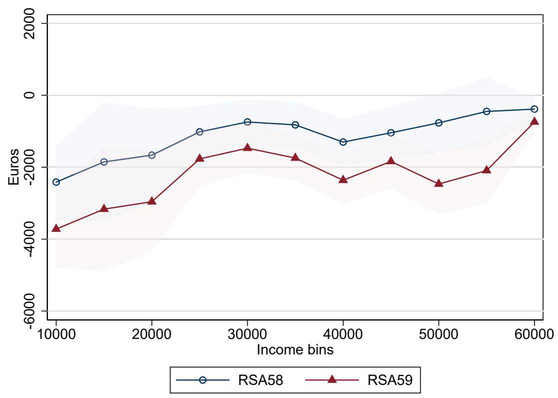
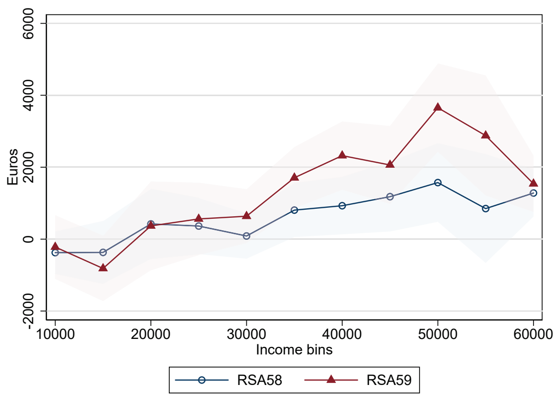


Figure 3.16: Effect of stricter screening by income bins

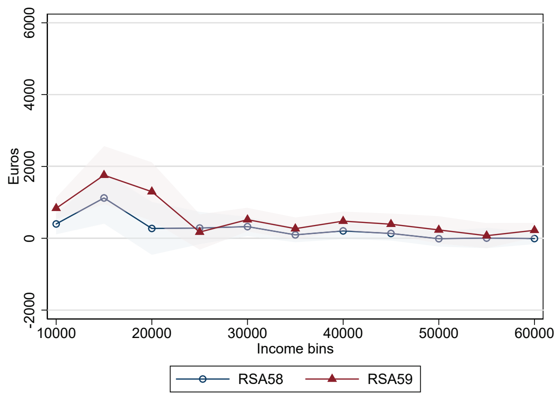
(a) DI benefits



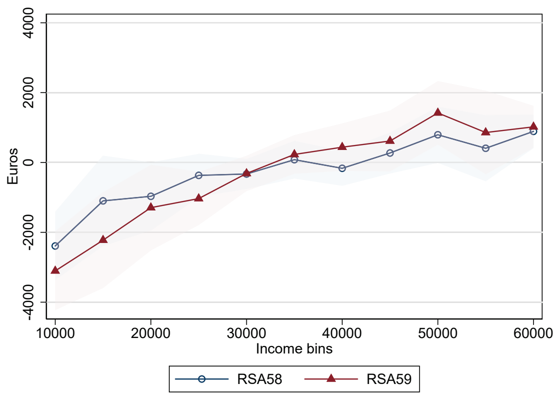
(b) Earnings



(c) Other benefis



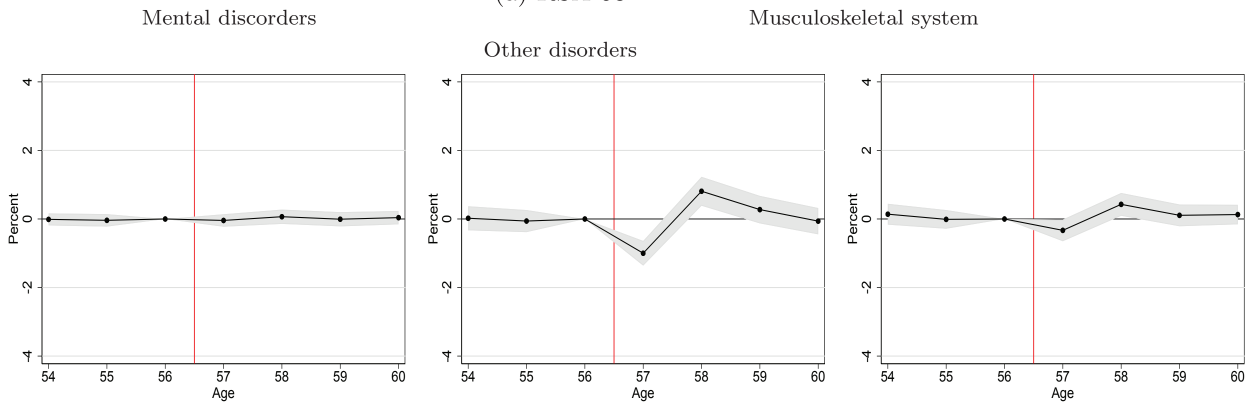
(d) Total income



3.A.5 Effect of screening benefit generosity application impairments

Figure 3.17: Application impairment, eligible men

(a) RSA 58



(b) RSA 59

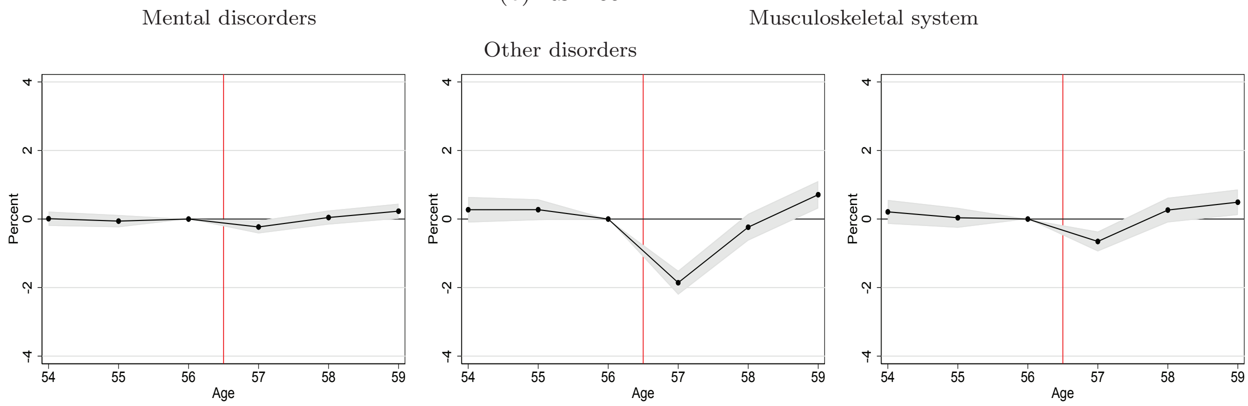


Table 3.9: Effect of benefit generosity on application impairment

	Ages 56-59		Ages 50-55		Ages 30-49	
	Estimate	Mean	Estimate	Mean	Estimate	Mean
Mental disorders	0.002	0.38	-0.001	0.26	<0.001	0.02
	(0.004)		(0.002)		(0.001)	
Musculoskeletal system	0.051***	1.62	-0.004**	0.48	-0.001	0.06
	(0.008)		(0.002)		(0.001)	
Other disorders	0.087***	3.42	0.078***	1.4	0.009***	0.27
	(0.022)		(0.008)		(0.002)	
Observations	1,575,659		3,377,731		12,989,251	

3.B Theory

3.B.1 Static Model

Welfare Effect Strictness of Screening. Starting from (3.3) the welfare effect of changing θ^* is given by

$$\begin{aligned}\frac{\partial W}{\partial \theta^*} &= -u'(w-\tau)\frac{\partial \tau}{\partial \theta^*} + \int_{\theta^A}^{\infty} \frac{\partial p(\theta;\theta^*)}{\partial \theta^*} v(b) dF(\theta) - \int_{\theta^A}^{\theta^R} \frac{\partial p(\theta;\theta^*)}{\partial \theta^*}(u(w)-\theta)dF(\theta) \\ &- \int_{\theta^R}^{\infty} \frac{\partial p(\theta;\theta^*)}{\partial \theta^*} v(z) dF(\theta) + \frac{\partial \theta^A}{\partial \theta^*} p(\theta^A) f(\theta^A) \underbrace{\left(u(w) - v(b) + \frac{\psi}{p(\theta^A)} - \theta^A\right)}_{=0 \text{ by definition of } \theta^A}\end{aligned} \tag{3.18}$$

where

$$\frac{\partial \tau}{\partial \theta^*} = \int_{\theta^A}^{\infty} \frac{\partial p(\theta;\theta^*)}{\partial \theta^*} b dF(\theta) - b\frac{\partial \theta^A}{\partial \theta^*} p(\theta^A) f(\theta^A) - \int_{\theta^R}^{\infty} \frac{\partial p(\theta;\theta^*)}{\partial \theta^*} z dF(\theta) \tag{3.19}$$

following from the planner's budget constraint. Defining $B(\theta^*) \equiv b\left(\partial\theta^A/\partial\theta^*\right) p(\theta^A) f(\theta^A)$, $M_W \equiv -\int_{\theta^A}^{\theta^R} \left(\partial p(\theta;\theta^*)/\partial\theta^*\right) dF(\theta)$, $M_Z \equiv -\int_{\theta^R}^{\infty} \left(\partial p(\theta;\theta^*)/\partial\theta^*\right) dF(\theta)$ and $M(\theta^*) \equiv M_W b + M_Z(b-z)$, we can rewrite $-\partial\tau/\partial\theta^* = B(\theta^*) + M(\theta^*)$. Plugging these terms into the above equation for $\partial W/\partial\theta^*$ yields condition (3.5) in the main text.

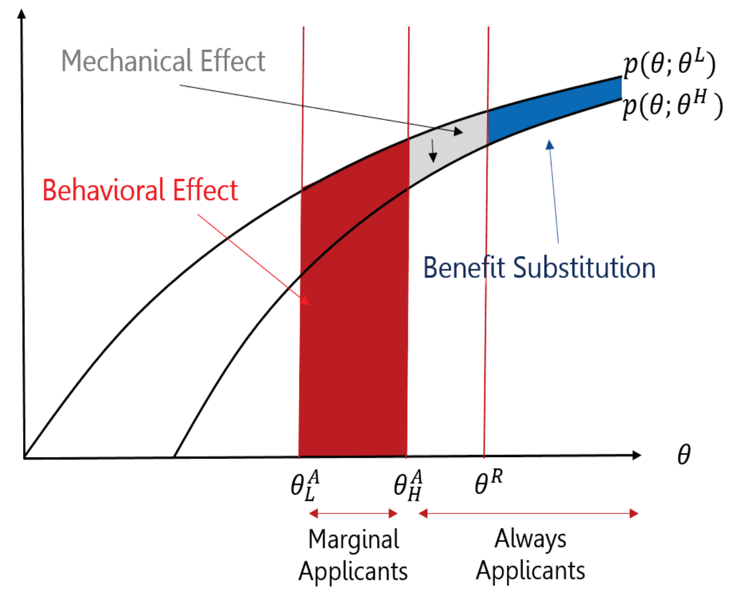
Welfare Effect Strictness of Screening: Non-marginal Change. Condition (3.5) in the main text holds for a marginal change in θ^*. Here we consider the welfare effect of a discrete change. Suppose strictness of screening increase from θ^L to $\theta^H > \theta^L$. This implies that the award probability falls $p(\theta;\theta^H) < p(\theta;\theta^L)$ and fewer individuals apply $\theta_H^A > \theta_L^A$ (θ_L^A denotes the marginal applicant with the lenient strictness of screening θ^L and θ_H^A denotes the marginal applicant with the high strictness of screening θ^H). Note θ^R is still independent of the strictness of screening.

Figure 3.18 illustrates the effects of a non-marginal change in strictness of screening. If screening becomes stricter, the award probability curve shifts down from $p(\theta;\theta^L)$ to $p(\theta;\theta^H)$. As a response fewer individuals apply. Individuals with $\theta < \theta_H^A$ no longer apply under the stricter rules. Individuals with $\theta \in \left[\theta_L^A, \theta_H^A\right]$ are therefore "marginal applicants" as they only apply under the lenient rules. The share of these marginal applicants is $\pi^{MA} = F(\theta_H^A) - F(\theta_L^A)$. The behavioral effect is the area under the old award curve of these marginal applicants. Individuals with a disability level above θ_H^A continue to apply. These are always applicants and their share is $\pi^{AA} = 1 - F(\theta_H^A)$. The difference between the old and new award curve for these always applicants corresponds to the mechanical effect. Some of these mechanically screened out individuals return to work (grey area) and some substitute to welfare benefits (blue area). Hence, we have the same effects as in the marginal case but these effects are slightly differently defined.

Let W_H and W_L denote welfare in the two screening regimes. Welfare in the two regimes $S \in \{H, L\}$ is

$$\begin{aligned} W_S = \; & u(w-\tau) + \textstyle\int_0^{\theta_S^A} (u(w)-\theta)dF(\theta) + \int_{\theta_S^A}^{\theta^R} (1-p(\theta;\theta^S))(u(w)-\theta)dF(\theta) + \\ & + \textstyle\int_{\theta_S^A}^{\infty} p(\theta;\theta^S)v(b)dF(\theta) + \int_{\theta^R}^{\infty}(1-p(\theta;\theta^S))v(z)dF(\theta) - \int_{\theta_S^A}^{\infty} \psi dF(\theta). \end{aligned} \tag{3.20}$$

Figure 3.18: Illustration Non-Marginal Change



Note: This figure illustrates the effects of a non-marginal change in strictness of screening.

The welfare effect of this discrete change $\Delta W \equiv W_H - W_L$ is given by

$$\begin{aligned}
\Delta W \quad = \quad & u(w-\tau^H) - u(w-\tau^L) \qquad (3.21)\\
& - \int_{\theta_H^A}^{\theta^R} \left[p(\theta;\theta^L) - p(\theta;\theta^H)\right] \left[v(b) - (u(w) - \theta)\right] dF(\theta) - \int_{\theta^R}^{\infty} \left[p(\theta;\theta^L) - p(\theta;\theta^H)\right] \left[v(b) - v(z)\right] dF(\theta)\\
& - \int_{\theta_L^A}^{\theta_H^A} p(\theta;\theta^L) \left[v(b) - (u(w) - \theta)\right] - \psi dF(\theta).
\end{aligned}$$

The first line of (3.21) captures the gain for the taxpayer (the fiscal cost reduction), the second line is the loss in insurance value for the always applicants (mechanically screened out). The third line is the insurance loss that marginal applicants experience and is the key difference to the marginal case. The Envelope theorem does not apply for a non-marginal change in θ^* and behavioral responses have a first order welfare effect. Note that for the limiting case of a marginal change $\theta^H \to \theta^L$ we have $\theta_H^A \to \theta_L^A$ and $\int_{\theta_L^A}^{\theta_H^A} p(\theta;\theta^L) \left[v(b) - (u(w) - \theta)\right] - \psi dF(\theta) \to p(\theta_L^A;\theta^L) \left[v(b) - (u(w) - \theta_L^A)\right] - \psi = 0$ by the definition of the marginal applicant θ_L^A.

Using the government budget constraint we can rewrite the fiscal effect again as the behavioral fiscal effect B_Δ plus the mechanical fiscal effect M_Δ:

$$\begin{aligned}
\tau^L - \tau^H \quad &= \quad \underbrace{b \cdot \int_{\theta_L^A}^{\theta_H^A} p(\theta;\theta^L) dF(\theta)}_{\equiv B_\Delta} \qquad (3.22)\\
&= \quad \underbrace{+b \cdot \int_{\theta_H^A}^{\theta^R} \left[p(\theta;\theta^L) - p(\theta;\theta^H)\right] dF(\theta) - (b-z) \cdot \int_{\theta^R}^{\infty} \left[p(\theta;\theta^L) - p(\theta;\theta^H)\right] dF(\theta)}_{\equiv M_\Delta}.
\end{aligned}$$

Moreover, we can write the welfare effect associated with the fiscal effect as $u(w-\tau^H)-u(w-\tau^L) = \lambda\left(\tau^L - \tau^H\right) = \lambda\left(B_\Delta + M_\Delta\right)$, where $\lambda = u'(w-\tau_\Delta)$ with τ_Δ such that this equality holds.[38] We can then rearrange (3.21) to $\Delta W \gtreqless 0 \Leftrightarrow$

$$1 + \frac{B_\Delta}{M_\Delta} \gtreqless \frac{L_{W\Delta} + L_{Z\Delta}}{u'(w-\tau_\Delta)M_\Delta} + \frac{L_{MA}}{u'(w-\tau_\Delta)M_\Delta} \tag{3.23}$$

where

$$L_{W\Delta} \equiv \int_{\theta_H^A}^{\theta^R} \left[p(\theta;\theta^L) - p(\theta;\theta^H)\right]\left[v(b) - (u(w)-\theta)\right] dF(\theta), \tag{3.24}$$

$$L_{Z\Delta} \equiv \int_{\theta^R}^{\infty} \left[p(\theta;\theta^L) - p(\theta;\theta^H)\right]\left[v(b) - v(z)\right] dF(\theta) \tag{3.25}$$

and

$$L_{MA} \equiv \int_{\theta_L^A}^{\theta_H^A} p(\theta;\theta^L)\left[v(b) - (u(w)-\theta)\right] - \psi dF(\theta). \tag{3.26}$$

In summary, the fiscal mutliplier is still key to evaluate the welfare effects and as we will see later on our empirical method to estimate the multiplier is robust to non-marginal changes. The insurance value is the discrete analog of the marginal change with an additional term L_{MA}.

Welfare Effect DI Benefit Level. Starting from equation (3.3) we get

$$\begin{aligned}\frac{\partial W}{\partial b} &= -u'(w-\tau)\frac{\partial \tau}{\partial b} + \int_{\theta^A}^{\infty} p(\theta;\theta^*)v'(b)dF(\theta) \\ &\quad + \frac{\partial \theta^A}{\partial \theta^*} p(\theta^A) f(\theta^A) \underbrace{\left(u(w) - v(b) + \frac{\psi}{p(\theta^A)} - \theta^A\right)}_{=0 \text{ by definition of } \theta^A}\end{aligned} \tag{3.27}$$

where $\partial\tau/\partial b = -b\left(\partial\theta^A/\partial b)p(\theta^A)f(\theta^A)\right) + \int_{\theta^A}^{\infty} p(\theta;\theta^*)dF(\theta) = B(b) + M(b)$ is the change in taxes necessary to fund a DI system with a marginally higher DI benefit b. (3.7) then immediately follows from (3.27).

3.B.2 General Model

DI Applications and Labor Supply. We proceed in a similar way as the discussion of static model in the main text. The setup mirrors the static model but extends it in two important dimensions. First, we extend the model to T periods, so agents need to make inter-temporal decisions. Second, we allow θ (and as well as other state variables such w) evolve stochastically over the agent's relevant time horizon. Let $X_{i,t} = \{\theta_{i,t}, A_{i,t}, \chi_{i,t}\}$ denote the vector of state variables where $\theta_{i,t}$ denotes agent i's disability level in period t, $A_{i,t}$ denotes the asset level and $\chi_{i,t}$ is a vector of other state variables (which allows for heterogeneity across agents such as differences in wages etc.). The state vector $X_{i,t}$ summarizes all the information relevant for agent i's choices in period t. The laws of motion of assets in the disability, employment and welfare

[38] Later on in the general model λ will denote the multiplier of the government budget constraint and therefore measures the social value of public funds.

benefit state are

$$
\begin{aligned}
A_{i,t+1} &= (1+r_t)A_{i,t} + b_{i,t}(X_{i,t}) - c^D_{i,t}(X_{i,t}) && (3.28)\\
A_{i,t+1} &= (1+r_t)A_{i,t} + w_{i,t}(X_{i,t}) - \tau_{i,t}(X_{i,t}) - c^E_{i,t}(X_{i,t}) && (3.29)\\
A_{i,t+1} &= (1+r_t)A_{i,t} + z_{i,t}(X_{i,t}) - c^Z_{i,t}(X_{i,t}). && (3.30)
\end{aligned}
$$

$b_{i,t}(X_{i,t})$ denotes DI benefits of individual i in period t and can depend on the agent's state $X_{i,t}$. Analogously, $w_{i,t}(X_{i,t})$ denotes labor income, $\tau_{i,t}(X_{i,t})$ are taxes and $z_{i,t}(X_{i,t})$ denotes social welfare benefits. Agents make state contingent plans on how much to consume in each labor market state $\left\{c^D_{i,t}(X_{i,t}), c^W_{i,t}(X_{i,t}), c^Z_{i,t}(X_{i,t})\right\}$, whether they apply to DI benefits $\alpha_{i,t}(X_{i,t}) \in \{0,1\}$ and, if not, on DI whether they work or claim social welfare benefits $\omega_{i,t}(X_{i,t}) \in \{0,1\}$.

The within-period sequence of events and choices is identical to the one of the static model in Section 2.1. At the beginning of the period, the shocks $\theta_{i,t}$ and $\chi_{i,t}$ are revealed. Having learned $X_{i,t}$, she decides whether to file a DI application and, if accepted, becomes a DI beneficiary for the rest of her life. [39] If her application is rejected, she either resumes work or claims social welfare, whatever yields higher utility.

Denote by $D_{i,t}, W_{i,t}$ and $Z_{i,t}$, respectively, the probability that, in period t, agent i is a DI benefit recipient, an employed worker, or a social welfare recipient. These probabilities are given by

$$
\begin{aligned}
D_{i,t} &= 1 - \left[\prod_{k=0}^{t}\left(1-\alpha_{i,k}(X_{i,k})\cdot p\left(\theta_{i,k},\theta^*_k\right)\right)\right] && (3.31)\\
W_{i,t} &= \omega_{i,t}(X_{i,t})\left[\prod_{k=0}^{t}\left(1-\alpha_{i,k}(X_{i,k})\cdot p\left(\theta_{i,k},\theta^*_k\right)\right)\right] && (3.32)\\
Z_{i,t} &= \left(1-\omega_{i,t}(X_{i,t})\right)\left[\prod_{k=0}^{t}\left(1-\alpha_{i,k}(X_{i,k})\cdot p\left(\theta_{i,k},\theta^*_k\right)\right)\right]. && (3.33)
\end{aligned}
$$

The probability agent i transitions to DI in period k is $\alpha_{i,k}(X_{i,k})\cdot p\left(\theta_{i,k},\theta^*_k\right)$. Hence, the probability that an agent is not yet on DI in period t is $\left[\prod_{k=0}^{t}\left(1-\alpha_{i,k}(X_{i,k})\cdot p\left(\theta_{i,k},\theta^*_k\right)\right)\right]$. From this pool, $\omega_{i,t}(X_{i,t})$ of the non DI individuals work and $1-\omega_{i,t}(X_{i,t})$ are on social welfare benefits.[40] We assume that the first application bears a fix cost ψ and follow-up applications are costless. $\Lambda_{i,t} = \alpha_{i,t}(X_{i,t})\prod_{k=0}^{t-1}\left(1-\alpha_{i,k}(X_{i,k})\right) \in 0,1$ indicates whether agent i applies for the first time in period t. The other state variables, disutility of work $\theta_{i,t}$ and $\chi_{i,t}$, follow stochastic processes that can, in principle, depend on agents' choices. The expectation operator $\mathbb{E}\left[\cdot\right]$ below captures the evolution of the state variables and encompasses aggregation across individuals and time. [41] The agent's problem is then given by

[39] The assumption that DI is an absorbing state, is supported by the empirically observed negligibly low outflow rates, particularly among older workers.

[40] We assume that social welfare, unlike DI, is not an absorbing state. This implies that an agent who has not yet entered DI is "at risk" of being employed or being on social welfare in period k, see equations (5) and (6) below.

[41] The expectation is with respect to the distribution of state variables, i.e. $\mathbb{E}\left[Y\right] = \int\int Y(X_{i,t})dF(X_{i,t})di$ where $F(\cdot)$ is the distribution of state variables $X(i,t)$. This is a flexible formulation. The only restriction we impose on this distribution of state variables is that it does not directly depend on the planner's policy instruments $P = \{\theta^*_t, b_t\}_{t=0}^{T-1}$. The evolution of $X(i,t)$, however, can depend on agent i's choices which themselves depend on the policy instruments P.

Note that the operator $E\left[Y\right] = \int Y(X_{i,t})dF(X_{i,t})$ simply denotes the expectation wrt. the state variables but does not integrate over individuals.

$$
\begin{aligned}
V_i(P) \quad = \quad & \max E\left[\sum_{t=0}^{T-1} \beta^t \left(v(c_{i,t}^D) \cdot D_{i,t} + v(c_{i,t}^Z) \cdot Z_{i,t} + \left(u(c_{i,t}^W) - \theta_{i,t}\right) \cdot W_{i,t} - \Lambda_{i,t} \cdot \psi\right)\right] \\
& + E\left[\sum_{t=0}^{T-1} \beta^t \mu_{i,t}^D \left((1+r_t)A_{i,t} + b_{i,t} - c_{i,t}^D - A_{i,t+1}\right) D_{i,t}\right] \\
& + E\left[\sum_{t=0}^{T-1} \beta^t \mu_{i,t}^W \left((1+r_t)A_{i,t} + w_{i,t} - \tau_{i,t} - c_{i,t}^W - A_{i,t+1}\right) W_{i,t}\right] \\
& + E\left[\sum_{t=0}^{T-1} \beta^t \mu_{i,t}^Z \left((1+r_t)A_{i,t} + z_{i,t} - c_{i,t}^Z - A_{i,t+1}\right) Z_{i,t}\right].
\end{aligned} \tag{3.34}
$$

Welfare Effect of DI Reforms. We proceed in the same way as we did in the static framework. We first set up the utilitarian planner's problem and study the impact of more stringent DI eligibility rules. The social planner maximizes social welfare by choosing the strictness of screening θ_s^* and DI benefit function b_s in each period s. We denote this disability policy by $P = \{\theta_s^*, b_s\}_{s=0}^{T-1}$. The planner therefore solves

$$
\max_P W(P) = \int_i V_i(P) di + \lambda \left(G(P) - \bar{G}\right) \tag{3.35}
$$

where

$$
G(P) = \int_i E\left[\sum_{t=0}^{T-1} (1+r_t)^{-t} \left(W_{i,t} \cdot \tau_{i,t} - D_{i,t} \cdot b_{i,t} - Z_{i,t} \cdot z_{i,t}\right)\right] di \tag{3.36}
$$

is the planners net revenue, $\bar{G}$ is an exogenous revenue constraint and λ denotes the Lagrange multiplier on the planner's budget constraint.

More Stringent DI Eligibility Rules. The following proposition characterizes the optimal DI policy $P = \{\theta_s^*, b_s\}_{s=0}^{T-1}$.

Proposition 1. *Assume the planner's budget constraint is differentiable in θ_s^* for all periods s. Optimal strictness of DI eligibility rules in period s, θ_s^*, then fulfills*

$$
1 + \frac{\mathbb{E}\left[B(\theta_s^*)\right]}{\mathbb{E}\left[M(\theta_s^*)\right]} = \frac{\mathbb{E}\left[L_W\right] + \mathbb{E}\left[L_Z\right]}{\lambda \mathbb{E}\left[M(\theta_s^*)\right]} \tag{3.37}
$$

where

$$
\mathbb{E}\left[M(\theta_s^*)\right] \equiv \mathbb{E}\left[\sum_{t=s}^{T-1} (1+r_t)^{-t} \left(M_{W_{i,t}}\left(b_{i,t} + \tau_{i,t}\right) + M_{Z_{i,t}}\left(b_{i,t} - z_{i,t}\right)\right)\right] \tag{3.38}
$$

is the mechanical fiscal effect and $\mathbb{E}\left[B(\theta_s^*)\right] \equiv \partial G(P)/\partial \theta_s^* - M$ is the behavioral fiscal effect. $M_{W_{i,t}}$ is the mechanical employment effect

$$
M_{W_{i,t}} \equiv -\omega_{i,t} \left(\alpha_{i,s} \cdot \frac{\partial p(\theta_{i,s}, \theta_s^*)}{\partial \theta_s^*} \prod_{k=0, k\neq s}^{t} (1 - \alpha_{i,k} p_{i,k})\right) \tag{3.39}
$$

and $M_{Z_{i,t}}$ is the mechanical benefit substitution effect

$$
M_{Z_{i,t}} \equiv -\left(1 - \omega_{i,t}\right) \left(\alpha_{i,s} \cdot \frac{\partial p(\theta_{i,s}, \theta_s^*)}{\partial \theta_s^*} \prod_{k=0, k\neq s}^{t} (1 - \alpha_{i,k} p_{i,k})\right). \tag{3.40}
$$

$\mathbb{E}[L_W]$ and $\mathbb{E}[L_Z]$ denote the insurance losses for individuals who return to work and substitute to welfare benefits respectively and are defined by

$$\mathbb{E}[L_W] \equiv \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(M_{W_{i,t}}\left(v_i(c_{i,t}^D) - \left(u_i(c_{i,t}^W) - \theta_{i,t}\right)\right)\right)\right] \tag{3.41}$$

$$\mathbb{E}[L_Z] \equiv \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(M_{Z_{i,t}}\left(v_i(c_{i,t}^D) - v_i(c_{i,t}^Z)\right)\right)\right]. \tag{3.42}$$

Proof. See below. □

Welfare Effect of Changing DI Benefits.

Proposition 2. *Assume the planner's budget constraint is differentiable in b_s for all periods s. The optimal DI benefit level in period s fulfills*

$$1 + \frac{\mathbb{E}[B(b_s)]}{\mathbb{E}[M(b_s)]} = \frac{\mathbb{E}\left[v'(c^D)\right]}{\lambda \cdot \mathbb{E}[M(b_s)]} \tag{3.43}$$

where $\mathbb{E}[M(b_s)] \equiv \mathbb{E}\left[(1+r_s)^{-s}(D_{i,s})\right]$ is the mechanical fiscal effect of adjusting DI benefits and $\mathbb{E}[B(b_s)] \equiv -\partial G(P)/\partial b_s - \mathbb{E}[M(b_s)]$ denotes the behavioral fiscal effect.

Proof. See below. □

Optimal Policy Mix: Gradient. From before we know

$$\frac{\partial W}{\partial \theta_s^*} = \gamma * \mathbb{E}[M(\theta_s^*)] * \lambda \tag{3.44}$$

where

$$\gamma \equiv 1 + \frac{\mathbb{E}[B(\theta_s^*)]}{\mathbb{E}[M(\theta_s^*)]} - \frac{\mathbb{E}[L_W] + \mathbb{E}[L_Z]}{\lambda \mathbb{E}[M(\theta_s^*)]} \tag{3.45}$$

and

$$\frac{\partial W}{\partial b_s} = \sigma * \mathbb{E}[M(b_s)] * \lambda \tag{3.46}$$

where

$$\sigma \equiv 1 + \frac{\mathbb{E}[B(b_s)]}{\mathbb{E}[M(b_s)]} - \frac{\mathbb{E}\left[v'(c^D)\right]}{\lambda \cdot \mathbb{E}[M(b_s)]}. \tag{3.47}$$

The gradient is then

$$\nabla W = \begin{pmatrix} \partial W/\partial b_s \\ \\ \partial W/\partial \theta_s^* \end{pmatrix} = \begin{pmatrix} \sigma * \mathbb{E}[M(b_s)] \\ \\ \gamma * \mathbb{E}[M(\theta_s^*)] \end{pmatrix} \lambda \tag{3.48}$$

and hence the optimal direction is given by

$$\left.\frac{\partial \theta^*}{\partial b}\right|_{opt} = \frac{\gamma}{\sigma} \cdot \frac{\mathbb{E}[M(\theta_s^*)]}{\mathbb{E}[M(b_s)]}. \tag{3.49}$$

Comparing Static and Dynamic Models Observe the similarity between the dynamic, general solution and the one of the static model. In the static model, we had

$$\frac{\partial W}{\partial \theta^*} \gtreqless 0 \iff 1 + \frac{B(\theta^*)}{M(\theta^*)} \gtreqless \frac{[v(b) - (u(w) - \tilde{\theta})]M_W + [v(b) - v(z)]\, M_Z}{u'(w-\tau)M(\theta^*)}$$

and in the dynamic model we have

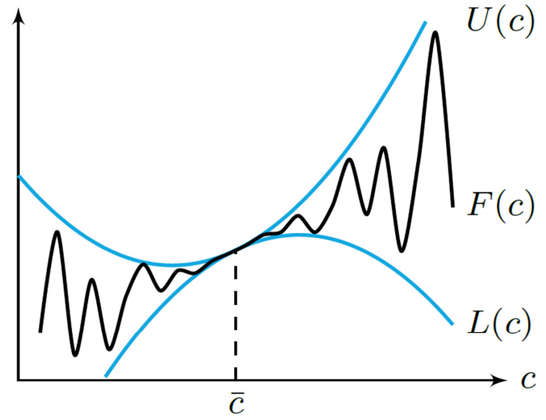
$$\frac{\partial W}{\partial \theta_s^*} \gtreqless 0 \iff 1 + \frac{\mathbb{E}[B(\theta_s^*)]}{\mathbb{E}[M(\theta_s^*)]} \gtreqless \frac{\mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(\left(v_i(c_{i,t}^D) - \left(u_i(c_{i,t}^W) - \theta_{i,t}\right)\right) M_{W_{i,t}} + \left(v_i(c_{i,t}^D) - v_i(c_{i,t}^Z)\right) M_{Z_{i,t}}\right)\right]}{\lambda \mathbb{E}[M(\theta_s^*)]}.$$

Proofs.

Proof. Proposition 1

The proof is a direct application of the Envelope Theorem. To derive conditions (3.37) and (3.43) we apply the differentiable sandwich lemma from **?**. **?** establish that if a function $F(c)$ is sandwiched at some point $\overline{c}$ between two differentiable functions (upper and lower support functions $U(c)$ and $L(c)$), then this function F is differentiable at this point $\overline{c}$. Moreover, the derivative of the sandwiched function F equals the derivative of the upper and lower support functions at this point, i.e. $F'(\overline{c}) = U'(\overline{c}) = L'(\overline{c})$. Figure 3.19 illustrates this idea nicely. The proof here therefore identifies differentiable upper and lower support functions of the welfare function $W(P)$.

Figure 3.19: Illustration Differentiable Sandwich Lemma



Notes: This Figure illustrates the differentiable sandwich lemma of **?**, which is the key argument in the proof of Proposition 1 and 2.
Source:**?**.

Let $\overline{P}$ denote the optimal policy, i.e. the $P = \{\theta_s^*, b_s\}_{s=0}^{T-1}$ that maximizes welfare. By definition $W(\overline{P}) \geq W(P)\,\forall P$ and therefore the constant function $U(P) = W(\overline{P})$ is a natural upper support function. We have $U'(P) = 0$.

For the lower support function we use the idea of the "lazy" decision maker who does not take into account agents' behavioral responses to the policy change. Let $\bar{V}_i(P)$ denote the agents indirect utility if she sticks to her behavior that is optimal for policy $\bar{P}$ even when the policy is changed to another P. That is, for all potential policies P the agent does not adjust her behavior. Therefore, $\bar{V}_i(P) \leq V_i(P)$. As a lower support function we then take $L(P) = \int \bar{V}_i(P)di + \lambda\left(G(P) - \bar{G}\right)$. The derivative of this lower support function with respect to θ_s^* is

$$\begin{aligned}\frac{\partial L(P)}{\partial \theta_s^*} &= \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(\alpha_{i,s} \cdot \frac{\partial p(\theta_{i,s}, \theta_s^*)}{\partial \theta_s^*} \prod_{k=0,k\neq s}^{t} (1-\alpha_{i,k}p_{i,k})\right) \left\{v(c_{i,t}^D) - v(c_{i,t}^Z)\cdot(1-\omega_{i,t}) \ldots\right.\right. \\ &\qquad \left.\left.\ldots - \left(u(c_{i,t}^W) - \theta_{i,t}\right)\cdot \omega_{i,t}\right\}\right] + \lambda \frac{\partial G(P)}{\partial \theta_s^*}. \end{aligned} \tag{3.50}$$

We can decompose the total fiscal effect $\partial G(P)/\partial \theta_s^*$ into the mechanical and behavioral fiscal effect. The mechanical effect is

$$\mathbb{E}\left[M(\theta_s^*)\right] = -\mathbb{E}\left[\sum_{t=s}^{T-1} (1+r_t)^{-t} \left(\alpha_{i,s} \cdot \frac{\partial p(\theta_{i,s}, \theta_s^*)}{\partial \theta_s^*} \prod_{k=0,k\neq s}^{t} (1-\alpha_{i,k}p_{i,k})\right) \left(b_{i,t} + \tau_{i,t}\cdot\omega_{i,t} - z_{i,t}\cdot(1-\omega_{i,t})\right)\right]$$

and we define the behavioral fiscal effect as the residual $\mathbb{E}[B(\theta_s^*)] = \partial G(P)/\partial\theta_s^* - \mathbb{E}[M(\theta_s^*)]$.[42] The differentiable sandwich lemma then implies that $\partial W(P)/\partial\theta_s^* = \partial L(P)/\partial\theta_s^* = \partial U(P)/\partial\theta_s^* = 0$ at the optimal policy. It is then straightforward to rearrange (3.50) to (3.37). □

Proof. Proposition 2.

We apply the same logic to the optimal DI benefit policy as in the previous proof. We have

$$\frac{\partial L(P)}{\partial b_s} = \mathbb{E}\left[\beta^s \mu_{i,s}^D\right] + \lambda \frac{\partial G(P)}{\partial b_s}. \tag{3.51}$$

The agent's first order condition implies $\mathbb{E}\left[\beta^s \mu_{i,s}^D\right] = \mathbb{E}\left[\beta^s v'(c_{i,s}^D)\right]$. Define the mechanical fiscal effect as $\mathbb{E}[M(b_s)] = \mathbb{E}\left[(1+r_s)^{-s}(D_{i,s})\right]$ and the behavioral fiscal effect is again defined as the difference between total fiscal effect and mechanical fiscal effect $\mathbb{E}[B(b_s)] = -\partial G(P)/\partial b_s - \mathbb{E}[M(b_s)]$. We again have $\partial W(P)/\partial b_s = \partial L(P)/\partial b_s = \partial U(P)/\partial b_s = 0$. It is then straightforward to rearrange (3.51) to obtain (3.43). □

Welfare Effect Strictness of Screening: Non-marginal Change. Analogous to the discussion in the static model, consider a discrete change in strictness of screening in period s from θ_s^L to $\theta_s^H > \theta_s^L$. To resemble our empirical setup assume that strictness of screening is high, $\theta^* = \theta^H$, until age s and lenient afterwards. This is denoted by policy $P^L = (\theta_0^H, \ldots, \theta_{s-1}^H, \theta_s^L, \theta_{s+1}^L, \theta_{T-1}^*; b_0, \ldots, b_{T-1})$. The reform we study empirically increased the age of relaxed screening from s to $s+1$. This corresponds to policy $P^H = (\theta_0^H, \ldots, \theta_{s-1}^H, \theta_s^H, \theta_{s+1}^L, \theta_{T-1}^*; b_0, \ldots, b_{T-1})$. Let $a_{i,t}^H$ denote the application decision of individual i in period t if the policy is P^H and $a_{i,t}^L$ denote the application decision under policy P^L. The discrete welfare effect is

$$\begin{aligned} \Delta W &= W(P^H) - W(P^L) \\ &= \int_i V_i(P^H) - V_i(P^L) di + \lambda\left(G(P^H) - G(P^L)\right) \end{aligned} \tag{3.52}$$

assuming that λ is the same under both policies. We can again decompose the fiscal effect $G(P^H) - G(P^L)$ into the mechanical and behavioral fiscal effect. The mechanical fiscal effect is given by

$$\mathbb{E}[M_\Delta(\theta_s^*)] \equiv \mathbb{E}\left[\sum_{t=s}^{T-1} (1+r_t)^{-t}\left(M_{\Delta W_{i,t}}(b_{i,t} + \tau_{i,t}) + M_{\Delta Z_{i,t}}(b_{i,t} - z_{i,t})\right)\right] \tag{3.53}$$

where $M_{\Delta W_{i,t}}$ is the mechanical employment effect

$$M_{\Delta W_{i,t}} \equiv \omega_{i,t}\left(\alpha_{i,s}^H \cdot \left[p_{i,s}^L - p_{i,s}^H\right] \prod_{k=0, k\neq s}^{t} \left(1 - \alpha_{i,k}^H p_{i,k}\right)\right) \tag{3.54}$$

and $M_{\Delta Z_{i,t}}$ is the mechanical benefit substitution effect

$$M_{\Delta Z_{i,t}} \equiv (1 - \omega_{i,t})\left(\alpha_{i,s}^H \cdot \left[p_{i,s}^L - p_{i,s}^H\right] \prod_{k=0, k\neq s}^{t} \left(1 - \alpha_{i,k}^H p_{i,k}\right)\right). \tag{3.55}$$

The mechanical fiscal effect is, as in the static model, driven by always applicants, $\alpha_{i,s}^H = 1$ (those who apply under the strict rules at age s), and the change in their award probability $\left[p_{i,s}^L - p_{i,s}^H\right]$. The share of always applicants at age s is given by $\pi^{AA} = \mathbb{E}\left[\alpha_{i,s}^H \cdot \prod_{k=0}^{s-1}\left(1 - \alpha_{i,k}^H p_{i,k}\right)\right]$.[43] We

[42] The behavioral fiscal effect contains the fiscal effect of all changes in behavior by agents. For instance, changes in DI application behavior.

[43] The share of marginal applicants is $\pi^{MA} = \mathbb{E}\left[\left[\alpha_{i,s}^L - \alpha_{i,s}^H\right] \cdot \prod_{k=0}^{s-1}\left(1 - \alpha_{i,k}^H p_{i,k}\right)\right]$.

define the behavioral fiscal effect as the residual $\mathbb{E}\left[B_\Delta(\theta_s^*)\right] \equiv \left(G(P^H) - G(P^L)\right) - \mathbb{E}\left[M_\Delta(\theta_s^*)\right]$. The behavioral fiscal effect is driven by changes in the application behavior and potential other changes in behavior (which might affect the whole state distribution $F(X_{i,t})$). Writing out the behavioral fiscal effect is cumbersome because many margins can change. Empirically, we follow the same strategy by estimating the total fiscal effect and the mechanical fiscal effect and then calculate the behavioral fiscal effect as the residual.

Similarly, we can write the insurance loss as

$$\int_i V_i(P^H) - V_i(P^L)di = \mathbb{E}\left[L_{\Delta W}\right] + \mathbb{E}\left[L_{\Delta Z}\right] + \mathbb{E}\left[L_{MA}\right] \tag{3.56}$$

where

$$\mathbb{E}\left[L_{\Delta W}\right] \equiv \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(M_{\Delta W_{i,t}} \left(v_i(c_{i,t}^D) - \left(u_i(c_{i,t}^W) - \theta_{i,t}\right)\right)\right)\right] \tag{3.57}$$

$$\mathbb{E}\left[L_{\Delta Z}\right] \equiv \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(M_{\Delta Z_{i,t}} \left(v_i(c_{i,t}^D) - v_i(c_{i,t}^Z)\right)\right)\right] \tag{3.58}$$

and $\mathbb{E}\left[L_{MA}\right] \equiv \int_i V_i(P^H) - V_i(P^L)di - \mathbb{E}\left[L_{\Delta W}\right] - \mathbb{E}\left[L_{\Delta Z}\right] > 0$ is the utility loss associated with behavioral changes. The welfare effect of a discrete change is therefore $\Delta W \gtreqless 0 \Leftrightarrow$ if

$$1 + \frac{\mathbb{E}\left[B_\Delta(\theta_s^*)\right]}{\mathbb{E}\left[M_\Delta(\theta_s^*)\right]} \gtreqless \frac{\mathbb{E}\left[L_{\Delta W}\right] + \mathbb{E}\left[L_{\Delta Z}\right]}{\lambda \mathbb{E}\left[M_\Delta(\theta_s^*)\right]} + \frac{\mathbb{E}\left[L_{MA}\right]}{\lambda \mathbb{E}\left[M_\Delta(\theta_s^*)\right]}. \tag{3.59}$$

3.C Further Evidence from Complier Analysis

3.C.1 Framework for complier analysis

In this section, we describe the complier analysis for difference-in-differences settings, as outlined in De Chaisemartin and D'Haultfoeuille (2018); Jäger et al. (2019), to study the characteristics of marginal, always, and never applicants and enrollees. For the RSA 58 change, we focus on the ages 56 and 57 and compare the RSA 58 cohort to the RSA 57 cohort. Both cohorts face strict screening at age 56, but the RSA 57 cohort faces relaxed screening at age 57. For the RSA 59 increase, we focus on the ages 55 to 59 and compare the RSA 59 cohort to the RSA 57 cohort. The RSA 57 cohort faces relaxed screening at ages 57 and 58, while screening is strict for the RSA 59 cohort.

We denote by $a = A57, B57$ the age window where $A57$ is the age window above 67 and $B57$ is the age window below 57. We denote by $c = T, C$ the cohort where T is the RSA 57 cohort and C is the RSA 58 cohort (the RSA 59 cohort when we study the RSA 59 change). AP is an indicator whether an individual applies for DI benefits and DI is an indicator whether an individual is awarded DI benefits. We have a binary instrument Z, which is one if screening is relaxed and zero otherwise, that is $Z = 1$ for $(T, A57)$ and $Z = 0$ for $(T, B57), (C, A57)$, and $(C, B57)$. AP_0 and AP_1denote the potential values of AP for $Z = 0$ and $Z = 1$. Similarly, DI_0 and DI_1denote the potential values of DI for $Z = 0$ and $Z = 1$. Based on the potential outcomes, we distinguish between three groups of applicants : always applicants ($AP_0 = AP_1 = 1$), never applicants ($AP_0 = AP_1 = 0$), and marginal applicants who only apply when screening is relaxed ($AP_0 = 0$ and $AP_1 = 1$). We define the different groups of enrollees in the same way.

It is straightforward to estimate the expected value of a characteristic X for never applicants. If we assume $AP_1 - AP_0 \geq 0$ (the standard monotonicity assumption the instrumental variable literature), then all individuals in $(T, A57)$ who do not apply for DI are never applicants.[44] We can estimate the conditional value of a never applicant characteristic $E(X|AP_1 = 0, T, A57)$ by the

[44] The monotonicity assumption rules out defying applicants who would apply when screening is strict but not when screening is relaxed.

sample mean $\frac{1}{N^{na}_{T,A57}}\sum_{i\epsilon(T,A57)} X_i\cdot \mathbb{I}(AP_i = 0)$,where $N^{na}_{T,A57}$ is the number of people in $(T, A57)$ who do not apply for DI and $\mathbb{I}(AP_i = 0)$ is an indicator that is one if an individual has not applied for DI. We can use the same logic to estimate the expectecd value of a characteristic for a never enrollee.

Estimating the expected value of a characteristic for marginal applicants and always applicants is more challenging and requires additional assumptions. Jäger et al. (2019) describe the steps in detail in the appendix. The idea is that the expected value of a characteristic X for all applicants is a weighted average of the expected value for marginal and always applicants, where the weights represent the share of marginal applicants and always applicants among all applicants in $(T, A57)$. We can rearrange the weighted average to get an expression for the conditional value of a marginal applicant characteristic:

$$E(X|AP_0 = 0, AP_1 = 1, T, A57) = \frac{\pi^{ma} + \pi^{aa}}{\pi^{ma}} \cdot E(X|AP_1 = 1, T, A57) - \frac{\pi^{aa}}{\pi^{ma}} \cdot E(X|AP_0 = 1, AP_1 = 1, T, A57) \tag{3.60}$$

where π^{ma} and π^{aa} are the shares of marginal and always applicants.

We can estimate each term of the right-hand side of equation 3.60 empirically. We estimate the shares of each group of applicants with the following regression:

$$AP_{iac} = \alpha + \beta_a + \gamma_c + \delta\, Z_{ac} + \varepsilon_{iac}, \tag{3.61}$$

where i is individual, βa is a fixed effect for the age $a = A57$, and c is a fixed effect for the cohort $c = T$. If Z is independent from AP and application trends are the same across cohorts in the absence of relaxed screening, then$\pi^{aa} = \alpha + \beta + \gamma$ is the share of always applicants in the RSA 57 cohort, $\pi^{ma} = \delta$ is the share of marginal applicants, and $\pi^{na} = 1 - \pi^{aa} - \pi^{ma}$ is the share of never applicants (De Chaisemartin and D'Haultfoeuille (2018); Jäger et al. (2019)).[45] To estimate the share of always enrollees (π^{ae}), marginal enrollees (π^{me}) and never enrollees (π^{ne}) , we replace applications AP with awards DI in equation (3.61). We estimate the conditional value of an applicant characteristic $E(X|AP_1 = 1, T, A57)$ by the sample mean $\frac{1}{N^{a}_{T,A57}}\sum_{i\epsilon(T,A57)} X_i\cdot \mathbb{I}(AP_i = 1)$,where $N^{a}_{T.A57}$ is the number of applicants in $(T, A57)$ and $\mathbb{I}(AP_i = 1)$ is an indicator that is one if an individual has applied for DI.

Calculating $E(X|AP_0 = 1, AP_1 = 1, T, A57)$ is challenging, because we never get to see whether applicants in $(T, A57)$ would have applied if screening was strict, that is the potential outcome AP_0 is not observable. Because of montonicity we know that all applicants who apply when screening is relaxed also apply when screening is strict, allowing us to write $E(X|AP_0 = 1, AP_1 = 1, T, A57) = E(X|AP_0 = 1, T, A57)$. If in X are the same across cohorts in the absence of relaxed screening trends and Z is independent from AP and X, we can estimate $E(X|AP_0 = 1, T, A57)$ using the change in applications at age 57 for cohort C, that is $E(X|AP_0 = 1, T, A57) = E(X|AP_0 = 1, T, B57) + E(X|AP_0 = 1, C, A57) - E(X|AP_0 = 1, C, B57)$. We can estimate each element on the right-hand side by the corresponding sample mean: $\frac{1}{N^{a}_{T,B57}}\sum_{i\epsilon(T,B57)} X_i\cdot \mathbb{I}(AP_i = 1) + \frac{1}{N^{a}_{C,A57}}\sum_{i\epsilon(C,A57)} X_i\cdot \mathbb{I}(AP_i = 1) - \frac{1}{N^{a}_{C,B57}}\sum_{i\epsilon(C,B57)} X_i\cdot \mathbb{I}(AP_i = 1)$.

3.C.2 Complier analysis for the RSA 59 increase

3.C.3 Comparison of applicants and enrollees

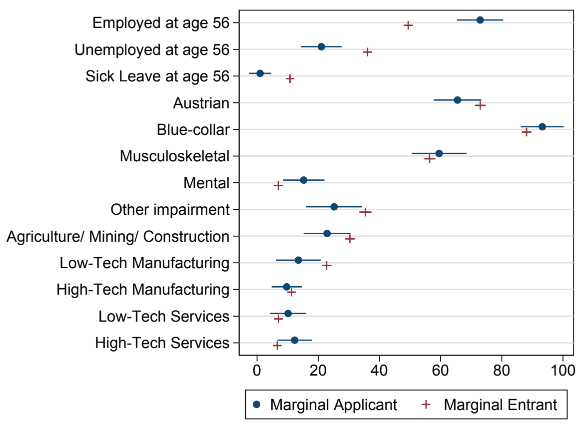
[45] Formaly, the independence assumption is equal to $AP_0, AP_1 \perp Z \mid a, c$ and the common trend assumption is equal to $E(AP_0|A57, T)$-$E(AP_0|B57, T) = E(AP_0|A57, C) - E(AP_0|B57, C)$.

Table 3.10: Applicant and enrollee characteristics, RSA 59

	Marginal-Applicants	Always-Applicants	Difference MA-AA	Never-Applicants	Difference MA-NA
A. Applicants					
Share in population	3.26***	10.18***	-6.93***	86.56***	-83.30***
	(0.10)	(0.09)	(0.18)	(0.05)	(0.13)
Sick Leave *at age 56*	-0.86	8.38***	-9.24***	0.92***	-1.77**
	(0.77)	(0.21)	(0.96)	(0.01)	(0.77)
Unemployed *at age 56*	10.61***	25.53***	-14.92***	4.25***	6.36***
	(1.52)	(0.42)	(1.90)	(0.03)	(1.52)
Employed *at age 56*	84.87***	62.80***	22.07***	87.15***	-2.28
	(1.89)	(0.52)	(2.36)	(0.05)	(1.90)
Blue-collar	85.87***	80.34***	5.53**	53.89***	31.98***
	(1.76)	(0.49)	(2.22)	(0.09)	(1.77)
Musculoskeletal	74.93***	36.37***	38.57***		
	(2.26)	(0.56)	(2.71)		
Mental	4.55***	17.83***	-13.27***		
	(1.66)	(0.49)	(2.10)		
Other	20.51***	45.80***	-25.29***		
	(2.11)	(0.57)	(2.61)		
B.Enrollees					
Share in population	8.00***	3.82***	4.19***	88.18***	-80.17***
	(0.09)	(0.07)	(0.15)	(0.05)	(0.12)
Sick Leave at age 56	6.41***	9.90***	-3.50***	0.83***	5.58***
	(0.19)	(0.27)	(0.43)	(0.01)	(0.19)
Unemployed at age 56	23.21***	16.92***	6.29***	4.67***	18.54***
	(0.32)	(0.44)	(0.70)	(0.03)	(0.32)
Employed at age 56	70.07***	64.31***	5.77***	86.79***	-16.72***
	(0.40)	(0.65)	(0.98)	(0.05)	(0.40)
Blue-collar	87.69***	72.73***	14.96***	54.24***	33.45***
	(0.47)	(0.68)	(1.08)	(0.09)	(0.47)
Musculoskeletal	57.28***	24.91***	32.37***		
	(0.54)	(0.71)	(1.11)		
Mental	7.43***	25.18***	-17.76***		
	(0.41)	(0.66)	(1.00)		
Other	30.57***	55.02***	-24.45***		
	(0.55)	(0.77)	(1.21)		

Figure 3.20: Comparison of Applicant and Entrant Compliers, RSA 58

(a) Marignal Applicant vs Marignal Entrant



(b) Always Applicant vs Always Entrant

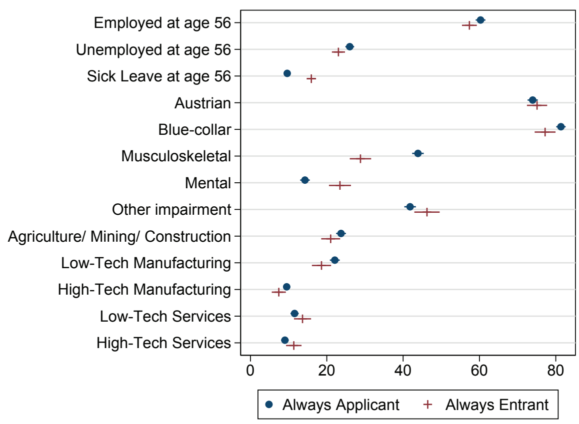
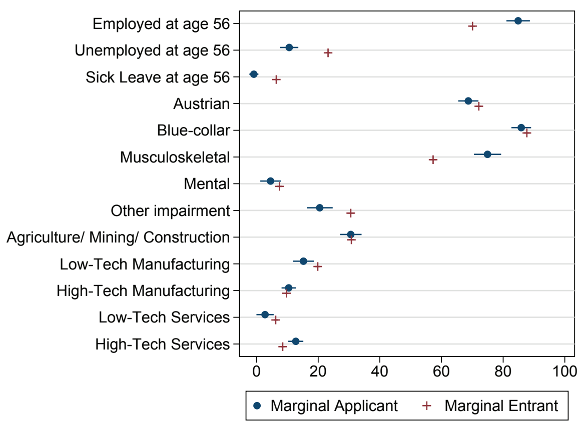
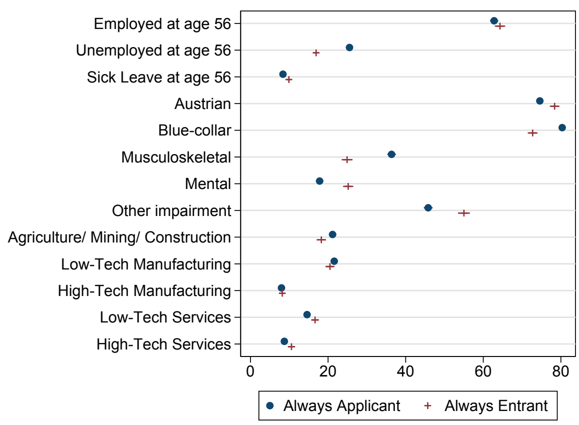


Figure 3.21: Comparison of Applicant and Entrant Compliers, RSA 59

(a) Marignal Applicant vs Marignal Entrant



(b) Always Applicant vs Always Entrant



3.D Welfare Implications

3.D.1 Strictness of Screening

Implementing the insurance value (the rhs of (3.13)) is associated with several challenges. In contrast to the sufficient statistics literature on UI, the utility loss is expressed in differences in utility levels rather than in marginal utilities. Moreover, the insurance value also depends on the abstract quantity θ. We tackle this challenges by deriving bounds of the insurance value that do not depend on the unobserved disability level θ. Furthermore, we assume utility is state-independent and CRRA, i.e. $v(c) = u(c) = \frac{c^{1-\gamma}-1}{1-\gamma}$, and that we have hand-to-mouth consumers.[46] In the following we discuss the derivation of the bounds and the implications of our assumptions. For

[46] We only observe transfers and incomes in our data and cannot measure consumption.

this define the insurance value as

$$\Delta V \equiv \frac{1}{\lambda \mathbb{E}\left[M(\theta_s^*)\right]} \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(M_{W_{i,t}}\left(v(c_{i,t}^D) - \left(u(c_{i,t}^W) - \theta_{i,t}\right)\right) + M_{Z_{i,t}}\left(v(c_{i,t}^D) - v(c_{i,t}^Z)\right)\right)\right] \quad (3.62)$$

In the following we derive lower and upper bounds on this insurance value ΔV.

Upper Bound Insurance Value. The social welfare benefits act as safety net. An agent cannot do worse than being on social welfare benefits in all periods. The insurance loss can therefore not be larger than

$$\Delta V \leq \frac{1}{\lambda \mathbb{E}\left[M(\theta_s^*)\right]} \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(M_{W_{i,t}} + M_{Z_{i,t}}\right)\left(v(c_{i,t}^D) - v(c_{i,t}^Z)\right)\right]. \quad (3.63)$$

This bound assumes that individuals who are screened out are all on social welfare benefits. Individuals who decide to work at some points can only do better than being on social welfare benefits in all periods and hence experience a lower insurance loss than assumed by this bound.

Lower Bound Insurance Value. Since $M_{W_{i,t}}\left(v(c_{i,t}^D) - \left(u(c_{i,t}^W) - \theta_{i,t}\right)\right) \geq 0$ we have

$$\Delta V \geq \frac{1}{\lambda \mathbb{E}\left[M(\theta_s^*)\right]} \mathbb{E}\left[\sum_{t=s}^{T-1} \beta^t \left(M_{Z_{i,t}}\left(v(c_{i,t}^D) - v(c_{i,t}^Z)\right)\right)\right]. \quad (3.64)$$

This lower bound simply assumes that individuals who are screened out and then return to work have no loss in insurance value, i.e. they are indifferent between working and receiving DI benefits.

Implementation. To implement (3.63) we make four assumptions. First, we measure the insurance loss relative to an increase in resources during an employment spell ($\lambda = \mathbb{E}\left[\sum_{t=0}^{T-1} \beta^t u'(c_{i,t}^W)\right]$ where $c_{i,W}$ is the consumption level of working individuals). This is the standard to measure the insurance value in the UI literature. Second, we assume utility is state-independent and CRRA, i.e. $v(c) = u(c) = \frac{c^{1-\gamma}-1}{1-\gamma}$. Third, we assume individuals are hand-to-mouth and set consumption equal to current income ($c_{i,t}^D = b_{i,t}, c_{i,t}^Z = z_{i,t}, c_{i,t}^W = w_{i,t}$). We assume this because we cannot observe consumption in our data. This assumption provides an upper bound on the insurance value. If individuals can self-insure through savings the insurance loss is smaller than if they were hand-to-mouth and simply consumed their income. Hence, in our implementation we tend to overestimate the insurance loss. Fourth, we assume no discounting $\beta = (1+r) = 1$. All effects are within a 5 years horizon and hence discounting does not play a major role.

With these assumptions we have

$$\Delta V \leq \frac{1}{\mathbb{E}\left[\sum_{t=0}^{T-1} \beta^t u'(c_{i,t}^W)\right] \mathbb{E}\left[M(\theta_s^*)\right]} \mathbb{E}\left[\sum_{t=s}^{T-1} \left(M_{W_{i,t}} + M_{Z_{i,t}}\right) \frac{1}{1-\gamma}\left((b_{i,t})^{1-\gamma} - (z_{i,t})^{1-\gamma}\right)\right] \quad (3.65)$$

and

$$\Delta V \geq \frac{1}{\mathbb{E}\left[\sum_{t=0}^{T-1} \beta^t u'(c_{i,t}^W)\right] \mathbb{E}\left[M(\theta_s^*)\right]} \mathbb{E}\left[\sum_{t=s}^{T-1} M_{Z_{i,t}} \frac{1}{1-\gamma}\left((b_{i,t})^{1-\gamma} - (z_{i,t})^{1-\gamma}\right)\right]. \quad (3.66)$$

We can directly calculate $\mathbb{E}\left[\sum_{t=0}^{T-1} \beta^t u'(c_{i,t}^W)\right]$ for a given value of risk aversion from the data and we estimate the mechanical fiscal effect $\mathbb{E}\left[M(\theta_s^*)\right]$ in Section 3.6. $\mathbb{E}\left[\sum_{t=s}^{T-1} \left(M_{W_{i,t}} + M_{Z_{i,t}}\right) \frac{1}{1-\gamma}\left((b_{i,t})^{1-\gamma} - (z_{i,t})^{1-\gamma}\right)\right]$

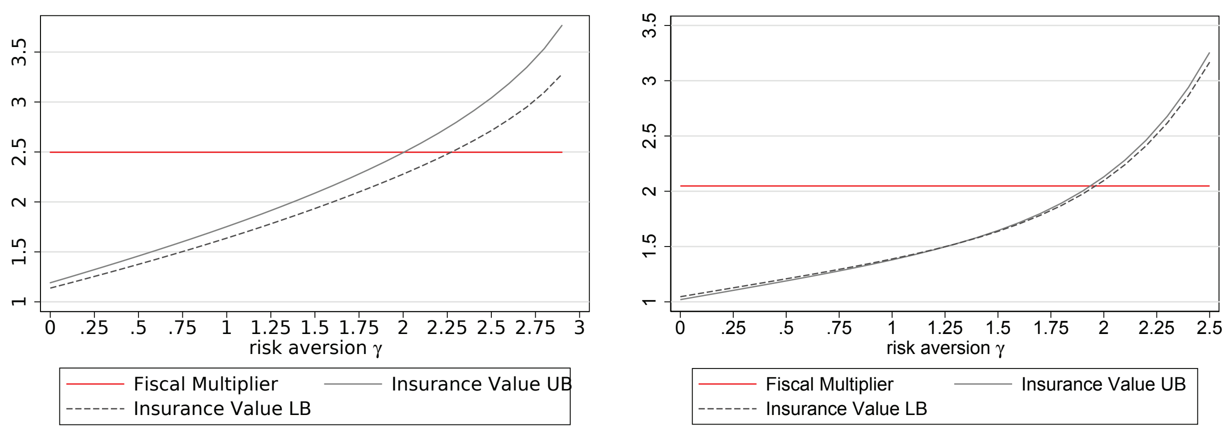
in (3.65) only depends on the mechanical effect. We therefore use the same counterfactual always applicants strategy as in the main text to estimate the mechanical fiscal effect. Here we just apply this strategy to a different outcome. For each individual we create a variable $q_{i,t}$ which is equal to the DI benefits $b_{i,t}$ if this individual is on DI benefits and equal to the individuals (hypothetical) social welfare benefits $z_{i,t}$ if this individual is not on DI benefits. This ensures that an individual who returns to work experiences a utility loss as if she was on social welfare benefits. We then calculate for a given risk aversion γ the utility $v_{i,t} = \frac{1}{1-\gamma}(q_{i,t})^{1-\gamma}$ and run our DiD strategy on this outcome variable $v_{i,t}$. Analogously to the mechanical fiscal effect this identifies the mechanical utility loss $\mathbb{E}\left[\sum_{t=s}^{T-1}\left(M_{W_{i,t}} + M_{Z_{i,t}}\right)\frac{1}{1-\gamma}\left((b_{i,t})^{1-\gamma} - (z_{i,t})^{1-\gamma}\right)\right]$.

To estimate $\mathbb{E}\left[\sum_{t=s}^{T-1} M_{Z_{i,t}}\frac{1}{1-\gamma}\left((b_{i,t})^{1-\gamma} - (z_{i,t})^{1-\gamma}\right)\right]$ in (3.66) we create a variable $l_{i,t}$ which is equal to the (hypothetical) DI benefits $b_{i,t}$ if this individual is on DI benefits or employed and equal to the individual social welfare benefits $z_{i,t}$ if this individual is on social welfare benefits. This ensures that an individual experiences no utility loss if she returns to work after being screened out (i.e. there is only a insurance loss if $M_{Z_{i,t}} = 1$). We then calculate for a given risk aversion γ the utility $u_{i,t} = \frac{1}{1-\gamma}(l_{i,t})^{1-\gamma}$ and run our DiD strategy on this outcome variable $u_{i,t}$.

Using this approach we estimate the upper and lower bound of the insurance loss for different values of risk aversion and plot the two bounds in Figure 3.22. We find that shifting the RSA by one year is welfare-improving if risk aversion $\gamma < 2$ and it is welfare-reducing if $\gamma > 2.3$. Increasing the RSA by two years is welfare-improving if risk aversion $\gamma < 1.95$. Estimates from the literature suggest that the coefficient of relative risk aversion is below 2, Chetty (2006b) finds an upper bound of $\gamma \leq 1.78$. Hence, our implementation implies that the increase in the RSA was welfare-improving for reasonable values of risk aversion.

Figure 3.22: Screening Stringency

(a) RSA 58 (b) RSA 59



Notes: Figure plots the LHS and the upper and lower bounds of the RHS of inequality (3.13) for the one year increase in the RSA from 57 to 58 in panel (a) and two year increase in RSA in panel (b) against different levels of risk aversion. If risk aversion is lower than the point where the solid grey line crosses the red line, then it is welfare improving to increase screening stringency. If risk aversion is higher than the point where the dashed grey line crosses the red line, then it is welfare improving to reduce screening stringency. For levels of risk aversion between these two points our sufficient statistics condition do not allow for a welfare statement.

3.D.2 Benefit Generosity

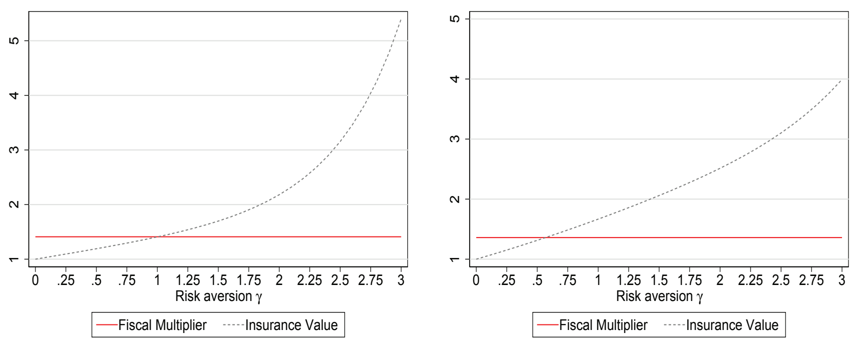
The effect we estimate empirically is a benefit reduction from age s to the end of life. For the welfare effect this simply implies that we need to sum up the welfare effects of changing benefits in each period. To implement the welfare effects we impose the same four assumptions as above in the screening implementation. This yields for the insurance value

$$\frac{\mathbb{E}\left[\sum_{t=s}^{T-1}(b_{i,s})^{-\gamma}\right]}{\mathbb{E}\left[\sum_{t=0}^{T-1}(w_{i,t})^{-\gamma}\right]}. \tag{3.67}$$

We can directly calculate this for different values of risk aversion based on the pre-reform benefit levels. Figure 3.23 plots the fiscal multiplier and the insurance value for different values of risk aversion. We find that for risk aversion around $\gamma = 1$ the benefit levels are optimal for the age group 56-59. Younger individuals have lower multipliers with similar insurance values and hence a lower critical risk aversion level of around $\gamma = 0.6$.Hence, benefit generosity is optimal for reasonable values of risk aversion.

Figure 3.23: Welfare Effects Benefit Generosity, Men

(a) Ages 56-59 (b) Ages 30-55



Notes: Figure plots the LHS and RHS of inequality (3.7) for men aged 56-59 in panel (a) and 30-55 in panel (b) against different levels of risk aversion. If risk aversion is higher than the point where the grey line crosses the red line, then it is welfare improving to increase benefit generosity. If risk aversion is lower than this point, it is welfare improving to reduce benefit generosity.

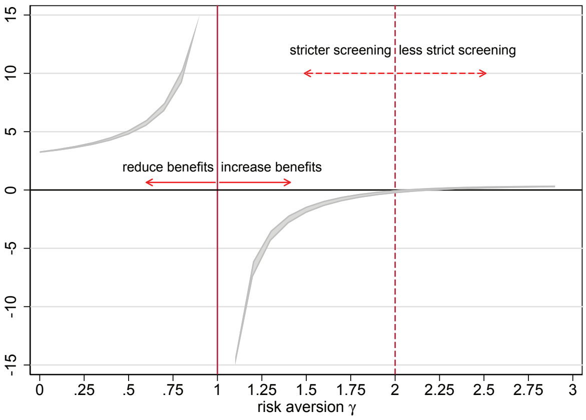
3.D.3 Gradient: Optimal Policy Mix

For the gradient we can use the implementation from above to express γ and σ as a function of risk aversion. For γ we use the upper and lower bounds and therefore get a range of optimal directions for a given level of risk aversion. The optimal direction $\frac{\gamma}{\sigma}$ measures the direction in units of mechanical cost reductions. Intuitively, the gradient says that for a one dollar mechanical reduction in fiscal costs due to lower benefits screening should be stricter such that $\frac{\gamma}{\sigma}$ dollars are saved mechanically. Figure 3.24 plots the Gradient for different values of risk aversion.

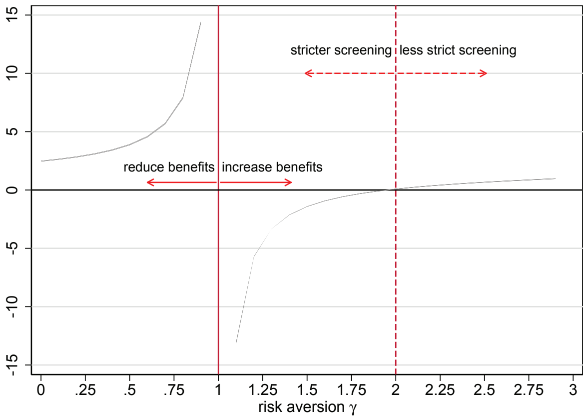
Figure 3.24 Panel (a) plots the optimal combination of changing benefit generosity and strictness of screening at age 57. For risk aversion below 1 benefits should be reduced and screening should be stricter. For instance with risk aversion of 0.5 the optimal combination reduces spending through stricter screening by 5 dollars for a one dollar reduction in spending due to lower benefits. Hence, at this level of risk aversion screening is optimally tightened more than benefits. For levels of risk aversion above 2, benefits should be increased and screening should be less strict. In this region it is more effective to increase benefits than to make screening less strict (optimal direction of around $\frac{d\theta^*}{db}$ ≈0.5).

Figure 3.24: Optimal Policy Mix: Gradient

(a) RSA 58



(b) RSA 59



Chapter 4

Offsetting the Cliff? A Sufficient Statistics Approach to Measuring the Welfare Effects of Work Incentives in Disability Insurance

joint with Giacomin Favre and Stefan Staubli

Abstract. Most disability insurance (DI) programs feature strong work disincentives, so called "cash cliffs". If DI beneficiaries have labor earnings beyond a certain income threshold, they loose their entire cash benefits. Instead, a benefit offset program reduces DI cash benefits gradually for individuals with an income above the threshold. Replacing a cash cliff with a benefit offset scheme has two opposing effects. On the one hand, the most able DI beneficiaries are incentivized to increase their labor supply (labor supply effect). This reduces program costs without reducing the insurance value of DI. On the other hand, DI becomes more attractive for potential applicants, which might cause more DI take-up (induced entry effect) and increased program costs. This paper develops robust sufficient-statistics formulas to evaluate the welfare effects of replacing a cash cliff with a benefit offset scheme. We show that the welfare effects crucially depend on two sufficient statistics: (i) the earnings elasticity of DI recipients and (ii) the DI benefit take-up elasticity. The earnings elasticity captures the labor supply effect, and the DI benefit take-up elasticity is a sufficient statistic for induced entry in a broad class of models. In an empirical application of our model, we plan to estimate these two sufficient statistics using two policy reforms in Canada with difference-in-differences and bunching estimators. Our preliminary analysis, using existing estimates from previous studies, finds that, for the U.S., it is unlikely that the introduction of a benefit offset reduces program expenditures. However, replacing the cash cliff with an offset can still be welfare improving for reasonable values of risk aversion.

4.1 Introduction

In many countries, the share of individuals receiving disability insurance (DI) has increased significantly over the past few decades. Autor et al. (2017) line out that in the United States the number of DI recipients has quintupled over five decades from 1 to over 5 percent and that European countries such as Norway exhibit an even stronger increase. The rapid expansion of the beneficiary population has generated substantial interest by policy makers and economists in measures that reduce growth in program caseloads and expenditures. Autor and Duggan (2006) discuss three ways to limit the expansion of DI programs: (i) provide incentives to return to work, (ii) reduce incentives to seek DI benefits, and (iii) adopt more rigorous eligibility standards. This paper focuses on (i), the optimal financial work incentives in DI.

DI programs are known for their strong work disincentives (Autor and Duggan, 2003, Bound et al., 2010). Most DI programs feature so called "cash cliffs": If DI beneficiaries supply work above a certain income threshold (the earnings disregard), they loose their entire cash benefits. Instead, a benefit offset program reduces DI cash benefits gradually for individuals with an income above the earnings disregard. Figure 4.1 illustrates a stylized budget set of DI beneficiaries under the cash cliff and the benefit offset regime. Intuitively, the introduction of a benefit offset scheme has two opposing effects. On the one hand, it can mitigate the inclusion error in DI. The most able DI beneficiaries are incentivized to increase their labor supply (labor supply effect). This reduces program costs without reducing the insurance value of DI. Empirical evidence on substantial remaining work capacity of some DI recipients[1] underlines the potential importance of this effect. On the other hand, the introduction of a benefit offset scheme makes DI more attractive for potential applicants. This might cause more DI take-up (induced entry effect), which increases program costs.

This paper formalizes the trade-off between labor supply and induced entry effect in a sufficient statistics model. For welfare analyses, we develop robust sufficient statistics formulas that capture the insurance value and incentive costs of benefit offset schemes. These formulas are functions of high-level elasticities that can be estimated using design-based empirical methods. We show that the welfare effects of moving from a cash cliff to a benefit offset regime crucially depend on two sufficient statistics: (i) the earnings elasticity of DI recipients and (ii) the DI benefit take-up elasticity.[2] The earnings elasticity captures the labor supply effect. The DI benefit take-up elasticity is a sufficient statistic for induced entry in a broad class of models. The contribution of our theoretical analysis is twofold. First, it provides simple yet robust sufficient statistics formulas to evaluate the welfare effects of introducing a benefit offset. Second, it sheds light on the potential size of the induced entry effect based on credible reduced form estimates. Estimating the induced entry effect is a key challenge. While the labor supply effect of a $1 for $2 benefit offset has been tested recently in the large benefit offset national demonstration (BOND) field experiment, the induced entry effect cannot be studied in a randomized controlled trial. The size of the induced entry is usually estimated by structural models (e.g. Hoynes and Moffitt, 1999 or Benitez-Silva et al., 2010). Our approach shows that in a broad class of models the DI benefit take-up elasticity is informative on the size of the induced entry effect.

We currently work on estimating both the benefit take-up elasticity and the earnings elasticity for Canada with data from the Longitudinal Administrative Database (LAD). Canada operates distinct DI programs for Quebec and the Rest of Canada (RoC). We exploit two policy reforms that provide exogenous variation in the DI benefit level and the earnings disregard in RoC but not in Quebec. This allows us to estimate the causal effects of the two reforms employing a difference-in-differences (DiD) identification strategy. Further, the earnings disregard allows us to estimate the earnings elasticity with a bunching estimator. This is work in progress. For the time being, we use estimates from previous studies to evaluate the welfare effects of introducing a benefit offset scheme. For the U.S., we find that it is unlikely that the introduction of a benefit offset scheme

[1] See for instance Maestas et al. (2013) and Autor et al. (2015).

[2] The DI benefit take-up elasticity denotes the elasticity of DI claiming with respect to benefit generosity, i.e. by how many percent DI claiming increases if DI benefits increase by one percent.

reduces program expenditures. However, replacing the cash cliff with an offset can be welfare improving for reasonable values of risk aversion depending on the benefit take-up elasticity. The estimates for the benefit take-up elasticity in the literature range from 0.1 to 0.9. For the smallest value, our sufficient statistic formula suggests that the introduction of a benefit offset is welfare improving. For the largest reported elasticity, it is better to keep the cash cliff, which acts as guard against undesirable DI applications. We hope to provide credible estimates of the benefit take-up elasticity with the empirical approach described above.

There is a growing empirical literature studying the effects of DI on labor market outcomes (e.g. Autor and Duggan 2003; de Jong, Lindeboom, and van der Klaauw 2011; Staubli 2011; Maestas, Mullen, and Strand 2013; Moore 2015; Gelber, Moore, and Strand 2017; French and Song 2014; Deshpande, Gross, and Su 2019) but empirical evidence on benefit offset schemes is scarce. A few countries test the effects of benefit offset schemes on the labor supply of DI beneficiaries. In the United States, the Social Security Administration recently ran a field experiment to test a benefit offset policy that reduces benefits by \$1 for every \$2 of earnings above the earnings disregard (in the U.S.: substantial gainful activity (SGA)). Gubits et al. 2018 document the final evaluation of this field experiment. They report that the probability of employment increased by 2 percent (0.4 percentage points) in the entire DI population and DI benefit payments increased by roughly 1 percent (\$12 per month). They conclude that the very small estimated increases in earnings (not statistically significant) were not sufficient to offset the deadweight loss from increases in taxes needed to fund larger DI benefit payments. Switzerland also conducted a field experiment on the introduction of a conditional cash program that incentivizes work but exhibited a very low take-up rate of 0.5 percent (Bütler et al., 2015). Campolieti and Riddell (2012) evaluate a shift in the earnings disregard in Canada. They report an increase in the extensive labor supply margin but no effect on program entry or exit. Kostol and Mogstad (2014) estimate the labor supply effects of a benefit offset scheme in Norway. In 2005, Norway introduced a benefit offset program that allowed DI beneficiaries to keep \$0.4 of every \$1 earned above an earning threshold. Because only DI beneficiaries who were already on DI before January 1 of 2004 became eligible for this benefit offset, they can use a regression discontinuity design to estimate the labor supply effects. They find substantial positive impacts on labor supply. Three years after implementation, this benefit offset increased labor force participation by 8.5 percentage points for DI recipients under age 50. Ruh and Staubli 2019 exploit bunching at the earnings disregard to identify the earnings elasticity of DI recipients in Austria and report an elasticity of 0.27. Gelber et al. (2017) study how differences in benefit levels reduce labor supply through an income effect of DI recipients in the United States documenting that this income effect accounts for a majority of DI-induced reductions in earnings. However, these studies and experiments can only identify the labor supply effect of individuals already on DI. The induced entry effect of benefit offset schemes is difficult to estimate with reduced form methods. Therefore, structural models are used to estimate the induced entry effect. Hoynes and Moffitt (1999) simulate the potential effects of a benefit offset for the U.S. in a calibrated model. More recently, Benitez-Silva et al. (2010) simulate the effect of the U.S. \$1 for \$2 offset in a structural model.

To our knowledge, there is very little theoretical research on work incentives in DI. Parsons (1996) shows that in a model with two-sided classification errors and two ability types, it is desirable to provide work incentives if there are no application fees. With application fees, a system without work incentives can be more efficient. Inderbitzin and Wallimann (2013) study the optimal work incentives with a distribution of ability types and an extensive margin labor supply choice. They find that the efficiency of work incentives depends on the relative size of labor supply and induced entry effects. In this sense, we generalize their model to include the intensive margin, which is the main target of work incentives in DI, and derive implementable sufficient statistics formulas.

The remainder of this paper is structured as follows. Section 4.2 describes our theoretical model. Section 4.3 discusses the welfare implications of our model employing existing estimates from the literature. Section 4.4 previews our empirical approach to estimating the labor supply and the benefit take-up elasticity for Canada. Section 4.5 concludes.

4.2 Model

In this section, we present a simple model of disability insurance (DI) based on the seminal work of Diamond and Sheshinski (1995). This model allows us to derive optimality conditions in terms of behavioral parameters that serve as sufficient statistics to evaluate the (local) optimality of work incentives in DI. Importantly, these behavioral parameters can be estimated empirically. We employ this model to study two questions: (1) Given a benefit offset scheme, what is the optimal offset rate r, i.e. what share of income above the earnings disregard should DI beneficiaries be allowed to keep? And (2) what are the fiscal and the welfare effects of replacing a cash cliff regime with a benefit offset scheme?

One key finding is that the answers to these two questions are closely related. We show that a cash cliff system can be modeled as a specific form of a benefit offset regime. Hence, shifting from a cash cliff to a benefit offset program is a special case of adjusting the offset rate. In section 4.2.1, we describe the model setup. Section 4.2.2 discusses the optimal offset rate, and section 4.2.3 discusses the welfare effects of replacing a cash cliff with a benefit offset.

4.2.1 Setup

We expand the seminal DI model of Diamond and Sheshinski (1995) by introducing an intensive labor supply choice and a two period structure. In the first period, the agent works, earns a wage w, and pays lump-sum taxes τ to finance the DI program. She does not save, does not make any other choices in the first period, and yields utility $u(w-\tau)$. In the second period, the agent suffers a disability shock θ, drawn from a continuous distribution $F(\theta)$.[3] After the agent observes the disability shock, she can choose whether to apply to DI and how much to work in either case.[4]

Labor Supply Decision Individuals with disability type θ choose their labor supply $z(\theta) \geq 0$ by maximizing

$$z(\theta) := \underset{z\geq 0}{\operatorname{argmax}}\, u(c(z)) - h(z, \theta), \tag{4.1}$$

where $h(z, \theta)$ denotes the disutility of labor of type θ when earning z, and $c(z)$ denotes disposable income. The wage rate is normalized to one for simplicity. We assume that $u_z > 0$, $u_{zz} < 0$, $h_z > 0$, $h_{zz} > 0$, $h_\theta > 0$, $h_{z\theta} > 0$, and $u(0) = h(0, \theta) = 0$ such that u is concave and h is convex. This implies a unique optimal labor supply, $z(\theta)$, for every θ, declining optimal labor supply in θ ($z'(\theta) \leq 0$), and convex indifference curves in consumption and labor income.[5]

Disposable Income For simplicity, we assume there are no taxes in the second period for non-DI recipients. Thus, their disposable labor income is given by $c(z) = z$. DI recipients face labor income taxes. We consider two tax regimes. A cash cliff scheme and a benefit offset regime.

A benefit offset scheme consists of three parameters (b, r, SGA). b are the base DI benefits, i.e. the benefits an individual receives if she works less than the threshold SGA. r is the marginal tax rate of labor income above SGA. Hence, r is the rate at which benefits are reduced for every dollar worked above SGA. An individual who earns labor income $z^B(\theta)$ has disposable income

$$c^B(\theta) = \begin{cases} b + z^B(\theta), & \text{if } z^B(\theta) \leq SGA \\ b + SGA + (1-r)(z^B(\theta) - SGA), & \text{if } z^B(\theta) > SGA \end{cases} \tag{4.2}$$

[3] We consider $\theta \in [0, \infty)$ as disability or "disutility of work". Thus, a higher θ corresponds to a more severe disability/higher disutility of work.

[4] For ease of exposition, we present the simplest possible model in the main text. In section 4.2.4 and the Appendix, we discuss various extensions, including the availability of other social insurance benefits (like unemployment insurance benefits), and show that our results hold in a broad class of models.

[5] Moreover, individuals with higher θ have steeper indifference curves, i.e. we have single crossing of indifference curves. Our theoretical insights do not rely on this specification with separability between consumption and disutility of work. Our insights apply for all specifications with convex preferences and single crossing of indifference curves for different θ-types. We chose this specification for notational simplicity.

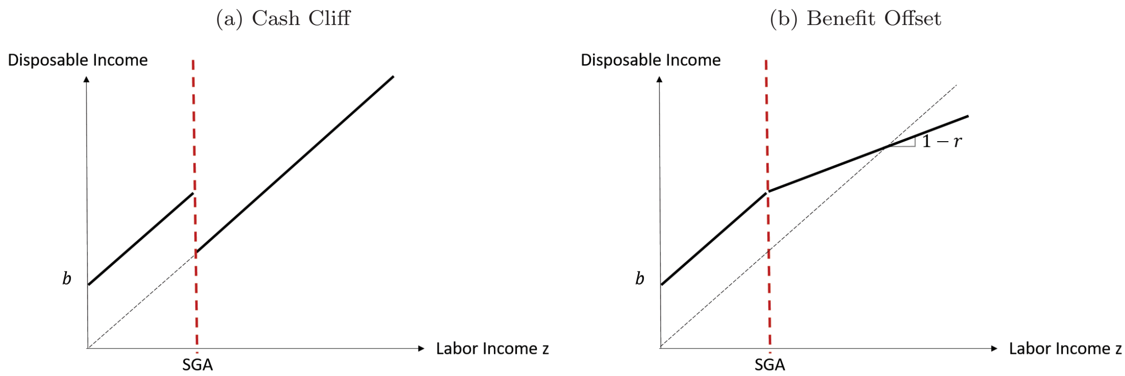
under a benefit offset scheme. With $r = 1$, benefits would be reduced one by one with labor income above SGA. With $r = 0$ benefits are independent of earnings. A lower r, therefore, corresponds to higher work incentives and lower benefit offset.

DI with a cash cliff is characterized by two parameters (b, SGA), where b are the DI benefits an individual receives as long as she earns a labor income below the earnings disregard SGA. If she earns above SGA she looses all her benefits. Hence, under a cash cliff an individual with optimal labor supply $z^C(\theta)$ has disposable income

$$c^C(\theta) = \begin{cases} b + z^C(\theta), & \text{if } z^C(\theta) \leq SGA \\ z^C(\theta), & \text{if } z^C(\theta) > SGA. \end{cases} \tag{4.3}$$

Figure 4.1 illustrates the budget set of individuals under the cash cliff vs. the benefit offset scheme. The black dotted line represents the budget set of non-DI recipients.

Figure 4.1: Budget Sets under Cash Cliff vs. Benefit Offset Scheme



Note: b denotes the base DI benefits, SGA the earnings disregard, and r the offset rate.

DI Application Decision There exists a unique marginal DI applicant θ^A. Individuals with a smaller disutility of work than the marginal applicant ($\theta < \theta^A$) do not apply for DI benefits, work according to their optimal labor supply choice $z(\theta)$, and receive utility $u(z(\theta)) - h(z(\theta), \theta)$. Individuals with larger disutility of work than the marginal applicant ($\theta \geq \theta^A$) apply for DI benefits. As in Diamond and Sheshinski (1995), a DI application is accepted with probability $p(\theta)$, where p increases in θ. An accepted applicant chooses her optimal labor supply $z^i(\theta)$, yielding second-period utility $u(c^i(\theta)) - h(z^i(\theta), \theta)$ where $i \in \{B, C\}$, depending on whether there is a benefit offset (B) or cash cliff (C) regime in place. A rejected applicant goes back to work and gets second-period utility $u(z(\theta)) - h(z(\theta), \theta)$.

4.2.2 Optimal Benefit Offset r

Under a benefit offset regime with parameters (b, r, SGA), social welfare is given by

$$\begin{aligned} W = & u(w - \tau) + \int_0^{\theta^A} u(z(\theta)) - h(z(\theta), \theta) dF(\theta) + \int_{\theta^A}^{\infty} p(\theta)[u(c^B(\theta)) - h(z^B(\theta), \theta)] dF(\theta) \\ & + \int_{\theta^A}^{\infty} [1 - p(\theta)][u(z(\theta)) - h(z(\theta), \theta)] dF(\theta). \end{aligned} \tag{4.4}$$

The government budget constraint corresponds to

$$
\begin{aligned}
\tau &= \int_{\theta^A}^{\infty} p(\theta)\left(\mathbb{1}\{z^B(\theta) \le SGA\}b + \mathbb{1}\{z^B(\theta) > SGA\}\left[b - r(z^B(\theta) - SGA)\right]\right) dF(\theta) \\
&= \int_{\theta^A}^{\infty} p(\theta)(b - ry(\theta))dF(\theta), \qquad (4.5)
\end{aligned}
$$

where y is defined as income above the earnings disregard, i.e.

$$
y(\theta) = \begin{cases} z^B(\theta) - SGA, & \text{if } z^B(\theta) \ge SGA \\ 0, & \text{if } z^B(\theta) < SGA. \end{cases} \qquad (4.6)
$$

The marginal applicant θ^A is unique and determined by[6]

$$
u(b + SGA + (1-r)(z^B(\theta^A) - SGA)) - h(z^B(\theta^A), \theta^A) = u(z(\theta^A)) - h(z(\theta^A), \theta^A), \qquad (4.7)
$$

where $z^B(\theta^A)$ solves

$$
(1-r)u'(b + SGA + (1-r)(z^B(\theta^A) - SGA)) = h_z(z^B(\theta^A), \theta^A), \qquad (4.8)
$$

and $z(\theta^A)$ solves

$$
u'(z(\theta^A)) = h_z(z(\theta^A), \theta^A). \qquad (4.9)
$$

Moreover, we have $SGA \le z^B(\theta^A) < z_K$, where z_K is the intersection of the Benefit Offset and the regular budget set, and $z^B(\theta^A) < z(\theta^A)$.[7]

A marginal change in the offset rate r has a welfare effect of

$$
\frac{\partial W}{\partial r} = -u'(w - \tau)\frac{\partial \tau}{\partial r} - \underbrace{\int_{\theta^A}^{\infty} p(\theta)u'(c^B(\theta))y(\theta)dF(\theta)}_{\text{change in insurance value}}, \qquad (4.10)
$$

where

$$
\begin{aligned}
\frac{\partial \tau}{\partial r} = &- \underbrace{\frac{\partial \theta^A}{\partial r} f(\theta^A)p(\theta^A)}_{\text{induced entry effect}}\left[b - ry(\theta^A)\right] - r\int_{\theta^A}^{\infty} p(\theta) \underbrace{\frac{\partial y(\theta)}{\partial r}}_{\text{labor supply effect}} dF(\theta) \qquad (4.11) \\
&- \underbrace{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}_{\text{mechanical costs}}.
\end{aligned}
$$

Intuitively, lowering the offset rate r increases the insurance value for DI recipients, who earn above SGA, i.e. have $y(\theta) > 0$. All behavioral responses such as more labor supply and more applications do not have first order welfare effects because of the envelope theorem. The behavioral responses only enter through the fiscal effects $\partial\tau/\partial r$. The fiscal effects consist of three components. First, a lower benefit offset increases expenditures mechanically through lower taxes on labor incomes above the earnings disregard. Second, the labor supply incentives change, which causes a behavioral response of DI recipients' labor supply. Third, DI becomes more attractive for individuals with disutility of work just below the previous marginal applicant, which leads to more entry into DI.

From equation (4.10), it follows immediately that providing more work incentives, i.e. reducing r, is always welfare improving if this reduces program expenditures, i.e. $\partial\tau/\partial r > 0$. In this case,

[6] Note that this is an interior solution in the sense that the marginal applicant supplies more labor than SGA. In case the marginal applicant would actually want to work less than or at SGA, the benefit offset would not be effective. Hence, the scenario would correspond to the one discussed in section 4.2.3. Thus, we only consider benefit offset schemes with $1 - r \ge \frac{h_z(SGA,\theta^A)}{u'(b+SGA)}$ throughout the paper.

[7] For proof of this see Lemma 2 in the Appendix.

decreasing the benefit offset, r, is a Pareto improvement. However, $\partial\tau/\partial r > 0$ is rather unlikely to hold. Even in the absence of induced entry (i.e. $-\frac{\partial\theta^A}{\partial r} f(\theta^A)p(\theta^A)\left[b - ry(\theta^A)\right] = 0$), the labor supply effect would have to compensate the mechanical costs in order to reduce program expenditures (if there is induced entry, the labor supply effect needs to be even stronger). This means, we would, at least, need that

$$1 < -\int_{\theta^A}^{\infty} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta) \frac{r}{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)} =: \varepsilon, \tag{4.12}$$

where ε is the earnings elasticity of DI recipients who earn above the earnings disregard. Hence, for an expenditure reduction, we need, at least, an earnings elasticity above one. If there is a positive induced entry effect on top (i.e. $-\frac{\partial\theta^A}{\partial r} f(\theta^A)p(\theta^A)\left[b - ry(\theta^A)\right] < 0$), the earnings elasticity needs to be even larger. Earnings elasticities are estimated to be rather low, especially for DI recipients ranging from 0.1 to 0.3 (Kostol and Mogstad (2014); Koning and van Sonsbeek (2017); Ruh and Staubli (2019)). Therefore, it appears unlikely that higher work incentives reduce program expenditures.

Nevertheless, decreasing r can still have positive welfare effects even with increasing expenditures (since the insurance value increases in $1 - r$). To obtain a money metric of the welfare derivative, we divide equation (4.10) by $u'(w - \tau)$ to get

$$\frac{\partial\tilde{W}}{\partial r} = \frac{\partial W/\partial r}{u'(w-\tau)} = \Delta\tau - \int_{\theta^A}^{\infty} p(\theta)y(\theta)\frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)} dF(\theta), \tag{4.13}$$

where

$$\Delta\tau \equiv \underbrace{\frac{\partial\theta^A}{\partial r} f(\theta^A)p(\theta^A)\left[b - ry(\theta^A)\right]}_{\text{induced entry effect}} + \underbrace{\int_{\theta^A}^{\infty} p(\theta)r\frac{\partial y(\theta)}{\partial r} dF(\theta)}_{\Delta\text{labor supply}}. \tag{4.14}$$

As long as individuals are not fully insured already (i.e. $w - \tau > c^B(\theta^A)$, we have $u'(w - \tau) < u'(c^B(\theta^A))$. Hence, providing higher work incentives (decreasing r) is welfare improving $\left(\partial\tilde{W}/\partial r < 0\right)$ if the labor supply effect compensates for the induced entry effect.

In general, we can rewrite (4.13) to see that the sign of the welfare effect $\partial\tilde{W}/\partial r \lesseqgtr 0$ is equivalent to[8]

$$\frac{E[y(\theta)\frac{u'(c^B(\theta))-u'(w-\tau)}{u'(w-\tau)}|DI]}{E[y(\theta)|DI]} \gtreqless -\varepsilon + \nu\left(\frac{b - ry(\theta^A)}{E[y(\theta)|DI]}\right), \tag{4.15}$$

where ν is the DI take-up semi-elasticity with respect to r defined as

$$\nu = -\frac{\partial \int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{\partial r}\frac{1}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} = \frac{\partial\theta^A}{\partial r} f(\theta^A)p(\theta^A)\frac{1}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}, \tag{4.16}$$

and $E[y(\theta)|DI]$ denotes the average earnings of DI recipients above SGA, defined by

$$E[y(\theta)|DI] = \frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}, \tag{4.17}$$

and

$$E[y(\theta)\frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)}|DI] = \frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)\frac{u'(c^B(\theta))-u'(w-\tau)}{u'(w-\tau)}dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}. \tag{4.18}$$

[8]Note that the sign of the inequality switches. That is $\partial\tilde{W}/\partial r < 0$ if the left-hand side (LHS) of (4.15) is *larger* than the right-hand side (RHS).

The LHS of (4.15) captures the consumption smoothing benefit of higher work incentives. To implement the LHS, we need to parameterize the utility function or use a Taylor approximation to obtain an expression only depending on the coefficient of relative risk aversion.

The RHS of (4.15) captures the fiscal effects. In principle, the RHS consists of estimable quantities. The only challenge is the DI take-up semi-elasticity ν. Implicit differentiation of equation (4.7) characterizing the marginal applicant using the equalities from (4.8) and (4.9) shows that

$$\frac{\partial \theta^A}{\partial r} = \frac{u'(c^B(\theta^A))y(\theta^A)}{h_\theta(z(\theta^A),\theta^A) - h_\theta(z^B(\theta^A),\theta^A)} = -\frac{\partial \theta^A}{\partial b} y(\theta^A) = -\frac{\partial \theta^A}{\partial SGA}\frac{y(\theta^A)}{r}. \tag{4.19}$$

Therefore, we can rewrite (4.15) as

$$\frac{E[y(\theta)\frac{u'(c^B(\theta))-u'(w-\tau)}{u'(w-\tau)}|DI]}{E[y(\theta)|DI]} \gtrless -\varepsilon + \mu\left(\frac{b - ry(\theta^A)}{b}\right)\frac{y(\theta^A)}{E[y(\theta)|DI]}, \tag{4.20}$$

where μ is the benefit take-up elasticity with respect to b

$$\mu = \frac{\partial \int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{\partial b}\frac{b}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} = -\frac{\partial \theta^A}{\partial b} f(\theta^A)p(\theta^A)\frac{b}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}. \tag{4.21}$$

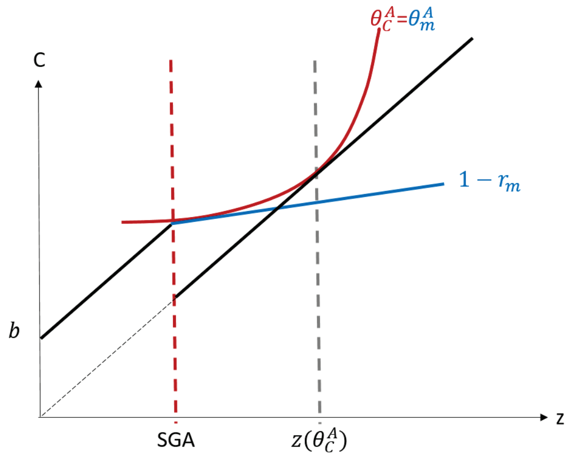
Therefore, the benefit take-up elasticity μ is a sufficient statistic for the induced entry effect. This elasticity is easier to estimate with reduced form methods since one does not rely on policies that change the benefit offset but only the DI benefit level. Consequently, increasing (decreasing) the offset rate increases welfare if the LHS of equation (4.20) is larger (smaller) than the RHS.

4.2.3 Moving from Cash Cliff to Benefit Offset

Section 4.2.2 developed a sufficient statistic formula to evaluate the local optimality of the offset rate r. However, most DI programs feature cash cliffs and not benefit offset schemes. The relevant policy discussion, therefore, is whether a cash cliff should be replaced by a benefit offset. The key idea to our approach is that a cash cliff can be modeled as a benefit offset.

Figure 4.2 illustrates how we construct a hypothetical benefit offset that mirrors a cash cliff. The black line represents the budget set of a DI recipient. The black dotted line marks the budget set of non-recipients. The red line is the indifference curve of the marginal DI applicant in the cash cliff regime with disability θ^A_C. Every individual with a lower θ does not apply for DI. Everyone with a higher θ works at or below the earnings exempt SGA. The blue line marks the budget set of a hypothetical benefit offset regime. The hypothetical benefit offset has an offset rate $1 - r_m$, which is equivalent to the slope of the indifference curve of the marginal applicant at the cash cliff. Hence, this hypothetical benefit offset system has the same marginal applicant as the cash cliff regime (i.e. $\theta^A_m = \theta^A_C$). For types with higher disability degree θ than the marginal applicant, the incentives to work and apply to DI are exactly the same. For types with lower θ than the marginal applicant, there is no difference between the two DI programs either.

Figure 4.2: Equivalence between Cash Cliff and Benefit Offset



Note: This figure illustrates the benefit offset scheme which is equivalent to the cash cliff. The benefit offset is determined by $1 - r_m = \frac{h_z(SGA, \theta_C^A)}{u'(b+SGA)}$. C denotes disposable income and z is labor income.

Replacing a cash cliff with a benefit offset is, therefore, equivalent to increasing labor supply incentives starting from this hypothetical benefit offset. To evaluate the welfare effects of a benefit offset introduction, we conduct the opposite thought experiment of moving from a benefit offset to cash cliff scheme, i.e. moving from a benefit offset with work incentives $r < r_m$ closer to r_m. This way we can start with $r = r_m - \epsilon$ (with $\epsilon > 0$) and consider the limiting case $\epsilon \to 0$. For all $\epsilon > 0$, we have an interior marginal applicant supplying more labor than SGA and can use the analysis from section 4.2.2. That is, we need to evaluate (4.20) for $r \to r_m$. This yields a much simpler sufficient statistic formula. Condition (4.20) becomes

$$\frac{u'(b + SGA) - u'(w - \tau)}{u'(w - \tau)} \gtreqless -\varepsilon + \mu. \tag{4.22}$$

This is a powerful result. First, equation (4.22) implies that welfare increases with the introduction of a benefit offset regime with minimal labor incentives whenever the LHS is larger than the RHS. Second, this test might even be informative on whether there exists a welfare-improving benefit offset at all if the welfare function were concave in r. The derivation of (4.22) is in Appendix 4.A.

4.2.4 Extensions

Our insights presented above are derived in a stylized model. In Appendix 4.B, we show that our results generally hold for: (1) any convex preferences with single crossing (as compared to separability of utility from consumption and disutility of work), (2) the presence of application costs to the DI program, (3) benefit substitution (i.e. the presence of other welfare programs), (4) labor adjustment costs, (5) other sources of heterogeneity (e.g. skill heterogeneity causing wage heterogeneity), and (6) one-period structure with taxes. The intuition for the robustness of our results is that we exploit envelope conditions to derive the welfare effects in terms of elasticities. The exact model specifications make some behavioral responses more and less elastic. Since, we estimate the elasticities with reduced form techniques, we do not need to know the exact model specifications. For instance, the presence of DI application costs could make the application decision less sensitive to financial incentives which would show up in a lower DI benefit take-up elasticity estimate.

4.3 Welfare Implications

As the empirical analysis is in process, we provide a first rough implementation of our sufficient statistic formulas for the United States. Thus, this section is merely for illustration purpose. Section 4.4 describes the planned empirical implementation for Canada.

The result of the theoretical model in section 4.2.3 has shown that evaluating how abolishing a cash cliff in favor of a benefit offset affects welfare can be achieved by estimating the quantities in the following equation

$$\frac{u'(b+SGA)-u'(w-\tau)}{u'(w-\tau)} \gtreqless -\varepsilon+\mu, \tag{4.23}$$

where b denotes the DI benefit level, SGA the earnings disregard (location of the cash cliff), w labor income in the first period (without disability), τ the lump sum taxes levied in the first period, ε the earnings elasticity, and μ the benefit take-up elasticity with respect to b.

Implementation of the LHS For the LHS, we use a quadratic approximation of the utility function to get[9]

$$\frac{u'(b+SGA)-u'(w-\tau)}{u'(w-\tau)} \approx \gamma\frac{w-\tau-(b+SGA)}{w-\tau} = \gamma\left(1-\frac{b+SGA}{w-\tau}\right), \tag{4.24}$$

where $\gamma = -\frac{u''(w-\tau)}{u'(w-\tau)}(w-\tau)$ is the coefficient of relative risk aversion evaluated at $w-\tau$. Hence, we need an estimate of the replacement rate for the marginal DI applicant (i.e. $(b+SGA)/(w-\tau)$). In the model, we rule out savings resulting in consumption being equal to income. However, the LHS should capture the consumption drop and not the income drop. Meyer and Mok (2018) study the income and consumption patterns of individuals reporting disabilities in the United States. They find that individuals reporting a chronic and severe disability face an after-tax post-transfer income drop of 30 percent ten years after onset of the condition. Consumption reacts less. Hence, focusing on income can be seen as an upper bound. Ideally, we would know the consumption drop of the marginal applicant. We want to exploit this more in the empirical implementation for Canada, where we might look at financial well-being and distress. For the time being, we use the income drop of 30 percent from Meyer and Mok (2018), i.e. $1-\frac{b+SGA}{w-\tau}=1-0.7=0.3$.[10]

Implementation of the RHS For the RHS, we need estimates for the DI take-up elasticity with respect to benefits μ and the earnings elasticity of DI recipients ε.

The take-up elasticity has not been directly estimated in the literature. Thus, we have to employ estimates of the *application* elasticity with respect to benefits and take award rates into account. To obtain an upper bound of the take-up elasticity, we multiply the application elasticity with the average award rate. This gives an upper bound since the individuals who actually react to the benefits (marginal applicants) should have lower than average award rates. First, Low and Pistaferri (2015) (Table 7) reports empirical estimates of the application benefit elasticity that range from 0.2 to 1.3 in the United States. Low and Pistaferri (2015)'s model implies an application benefit elasticity of 0.62. Second, French and Song (2014) find an award rate after 10 years from the initial application of 0.67 for the United States. Hence, we get a take-up elasticity μ ranging from 0.1 to 0.9.

We are not aware of a direct estimate of the earnings elasticity of the marginal DI applicant for the United States. Ruh and Staubli 2019 exploit bunching at the cash cliff in Austria and estimate an earnings elasticity of 0.27. Koning and van Sonsbeek (2017) report an elasticity of 0.12 for the Netherlands. Kostol and Mogstad (2014) find elasticity estimates between 0.1 and 0.3 for Norway.

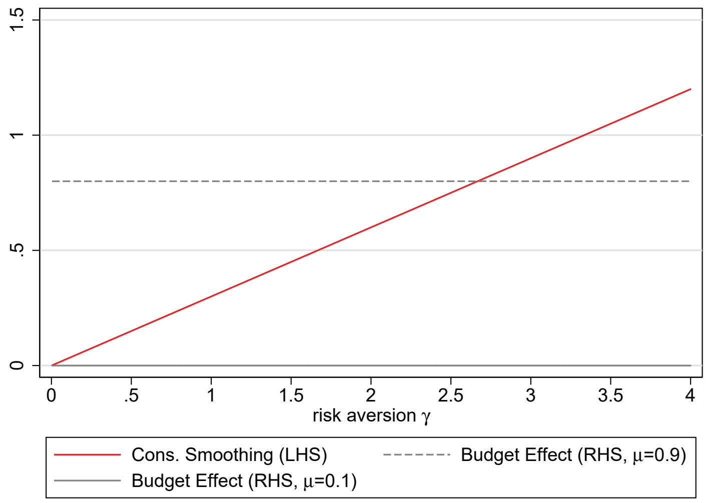
[9] This is a standard approach, see Chetty and Finkelstein (2013).

[10] Autor and Duggan (2003) (Table 1) report lower DI replacement rates. However, this replacement rate is before additional labor income from working up to the SGA (i.e. $b/(w-\tau)$ rather than $(b+SGA)/(w-\tau)$).

Evidence from the benefit field experiment in the United States indicates that the labor supply elasticity might be rather low (Weathers and Hemmeter (2011); Gubits et al. (2018)). Therefore, we use $\varepsilon = 0.1$.

Results Figure 4.3 illustrates the fiscal (RHS) and consumption smoothing effect (LHS) of introducing a benefit offset as a function of risk aversion. If the consumption smoothing benefits (red line) exceed the fiscal costs (gray lines), replacing the cash cliff with a benefit offset is welfare improving. We plot the fiscal effect for the largest ($\mu = 0.9$, dashed gray line) and smallest ($\mu = 0.1$, solid gray line) benefit take-up elasticity reported in the literature. For the smallest μ, introducing a benefit offset is welfare improving for all levels of risk aversion. For the highest μ, introducing a benefit offset is only welfare improving if risk aversion is rather large ($\gamma > 2.6$). Hence, for reasonable values of risk aversion it is better to keep a cash cliff regime.

Figure 4.3: Welfare Implications



Note: If the consumption smoothing effect (Cons. Smoothing) exceeds the fiscal costs (Budget Effect), introducing a benefit offset is welfare improving.

4.4 Empirical Implementation with Canadian Data

In this section, we report our empirical approach to implementing our sufficient statistics formula for Canada. We cannot show results yet as this is still work in progress and the results are not authorized for publication yet.

Framework In this empirical analysis, we estimate the effects of changes in the level of DI benefits and the earnings disregard on program entry/exit, labor supply, and financial well-being in Canada. This allows us to infer the earnings elasticity and benefit take-up elasticity with respect to the benefit level, which are the crucial parameters to implementing our sufficient statistics formula.

Canada operates two distinct DI programs for Quebec and the Rest of Canada (RoC). We can exploit exogenous variation in program parameters that is generated by two reforms to the Canadian Pension Plan DI program (CPP-D) that left the Quebec Pension Plan DI program (QPP-D) unchanged. The first reform took place in 1987 and increased the replacement rate of DI benefits by about 36 percent in RoC (Gruber, 2000). The second reform was implemented in 2001 and increased the earnings disregard in the CPP-D to CAD 3,800 per year (Campolieti and Riddell, 2012). These reforms were not implemented in Quebec enabling us to use the population of Quebec as a control group in this quasi-experiment.

Data We work with the Canadian Longitudinal Administrative Database (LAD). The LAD contains detailed information of 20 percent of individuals (and their spouse and children) filing an income tax return between 1982 and 2016. Importantly for our context, the LAD also contains information on the receipt of DI benefits, demographics, earnings, income, other government transfers, savings, taxes, and housing. Due to the detailed information on income and savings flows, we can study how changes in DI generosity not only affect labor supply and DI claiming, but also the social insurance provided by taxes and transfers.

Methods We will exploit exogenous variation in DI benefit levels and the earnings disregard caused by two policy reforms to the CPP-D in 1987 and 2001.

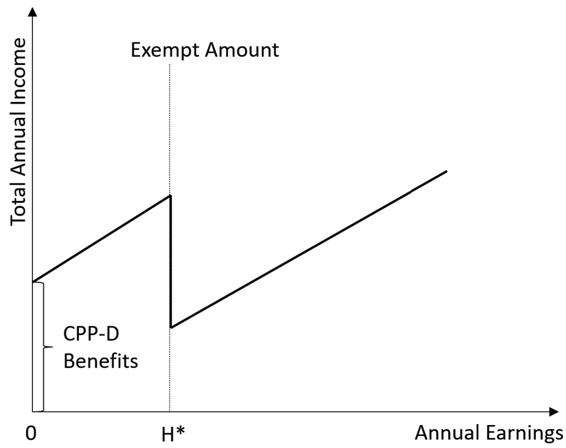
The 1987 CPP-D reform: Prior to 1987, the CPP-D pension was substantially less generous than the QPP-D pension. In an effort to align the two programs, the government increased the CPP-D pension in 1987 to the level of the QPP-D pension. This change increased the CPP-D pension by almost CAD 2,000 per year, corresponding to an average increase in the replacement rate of 36 percent (Gruber, 2000). We use a difference-in-differences (DiD) identification strategy to estimate the causal effects of this reform. Specifically, we compare the change in an outcome variable, for example earnings, in RoC with the change in the same outcome variable in Quebec before and after the reform. This comparison can be implemented with the following regression

$$y_{ijt} = \alpha + \beta T_{ijt} + \theta_j + \pi_t + X'_{ijt}\delta + \epsilon_{ijt}, \tag{4.25}$$

where y_{ijt} is an outcome variable of individual i living in province j in year t, T_{ijt} is a dummy that is equal to 1 if an individual lives in RoC after the reform, θ_j are province fixed effects, π_t are year fixed effects, and X_{ijt} is a vector of demographic and labor market characteristics (e.g. socioeconomic status, age, experience, or previous earnings). The coefficient of interest is β, which identifies the effect of the 1987 benefit increase on y_{ijt} under the assumption that trends in y_{ijt} would have been the same in RoC and Quebec in the absence of the reform. Using program entry and exit as outcome variables allows us to estimate the benefit take-up elasticity with respect to the benefit level. Analyzing the effect on earnings provides insights on the earnings elasticity. Apart from the implementation of our sufficient statistics formula, we will also contribute to the literature in analyzing the effects of the 1987 CPP-D reform in detail. Gruber (2000) studies the effect of the same reform on labor force non-participation, while we provide novel evidence on the effects on DI exit/entry, government transfers, and other financial outcomes such as savings and housing. Additionally, we will carefully investigate the validity of the "parallel trends" assumption. Lastly, we can zoom in to the border of Quebec and RoC similar to Campolieti and Riddell (2012) to have a more homogeneous sample in which the concern about non-parallel trends is likely to be less prevalent.

The 2001 CPP-D reform: In June 2001, the CPP-D introduced an annual earnings exemption allowing beneficiaries to earn up to CAD 3,800 without having their benefits suspended. The purpose of this policy was to encourage work among CPP-D beneficiaries. We apply two estimation strategies to examine the effect of the earnings exemption. The first strategy is a bunching estimator, which exploits the discontinuity in the implicit tax on work at the exempt threshold of CAD 3,800 (cash cliff). Specifically, the exempt amount causes a notch in the budget constraint in a static labor supply model, defined as a discrete increase in the (implicit) tax liability. This notch displayed in figure 4.4 creates a strong incentive for DI beneficiaries to keep their earnings just below the exempt threshold. This type of behavior is coined "bunching" and, as (Saez, 2010) shows, the amount of bunching can be used to estimate an earnings elasticity with respect to the net-of-tax rate. This parameter is crucial to assess the effectiveness of return-to-work programs (Ruh and Staubli, 2019) and to implement our sufficient statistics model. The second strategy is a DiD approach similar to the one shown in equation (4.25). Specifically, we compare the change in an outcome variable in RoC with the change in the same outcome variable in Quebec before and after the introduction of the earnings exemption in 2001. Campolieti and Riddell (2012) also study the 2001 reform, but they do not examine effects on beneficiaries' earnings, government transfers, and other financial outcomes.

Figure 4.4: Budget Constraint under CPP-D after the 2001 Reform



Note: This illustration corresponds to figure 4.1a in the theoretical part in section 2.2. H^* marks the earnings exemption (exempt amount) corresponding to SGA in the theoretical part. CPP-D benefits is the level of flat DI benefits labeled by b in section 2.2.

4.5 Conclusion

Most DI programs feature strong work disincentives for DI recipients. Usually DI recipients lose their entire DI cash benefits if their earnings surpass the earnings disregard (so called cash cliff). As an alternative, a benefit offset program reduces DI cash benefits gradually for individuals with an income above the earnings disregard. Offsetting the cash cliff causes two behavioral responses. First, DI recipients with substantial remaining work capacity are incentivized to increase labor supply (labor supply effect). This reduces program costs without reducing the insurance value of DI. Second, the more generous DI program is more attractive for potential applicants. This might cause more DI take-up (induced entry effect) and increase program costs.

In this paper, we formalize this trade-off between labor supply and induced entry effect. We develop robust sufficient statistics formulas that capture the insurance value and incentive costs of benefit offset schemes to analyze welfare effects. These formulas are functions of high-level elasticities that can be estimated empirically. We show that the welfare effects of moving from a cash cliff to a benefit offset regime crucially depend on two sufficient statistics: (i) the earnings elasticity of DI recipients and (ii) the DI benefit take-up elasticity with respect to the DI benefit level. The earnings elasticity captures the labor supply effect, and the DI benefit take-up elasticity is a sufficient statistic for induced entry in a broad class of models. Our theoretical analysis' contribution is twofold. First, it provides simple yet robust sufficient statistics formulas to evaluate the welfare effects of introducing a benefit offset. Second, it sheds light on the potential size of the induced entry effect based on credible reduced form estimates.

In an empirical application of our model, we plan to estimate these two sufficient statistics exploiting two policy reforms in Canada changing the level of DI benefits and the earnings exempt with difference-in-differences and bunching estimators. This is work in progress. For the time being, we use estimates from previous studies to evaluate the welfare effects of introducing a benefit offset scheme. For the U.S., we find that it is unlikely that the introduction of a benefit offset scheme reduces program expenditures if the benefit take-up elasticity is high. If the benefit take-up elasticity is very low, our sufficient statistics formula suggests that the introduction of a benefit offset is welfare improving. This shows the crucial importance of credibly estimating the benefit take-up elasticity. We hope to provide these credible estimates with our empirical approach for Canada.

4.A Proofs

We outlined the key idea and result of the equivalence between a cash cliff and benefit offset in the main text. Here we derive these insights formally. Before showing the equivalence we establish in Proposition 3 that there is no benefit offset that incentivizes labor supply but does not have an entry effect. Lemma 1 then establishes the equivalence between a cash cliff and a hypothetical benefit offset. Lemma 2 characterizes the marginal applicants under both regimes and afterwards we derive equation (4.22).

Welfare under a Cash Cliff system is given by

$$\begin{aligned} W^C =& u(w-\tau^C) + \int_0^{\theta_C^A} u(z(\theta)) - h(z(\theta),\theta) dF(\theta) \\ &+ \int_{\theta_C^A}^{\infty} p(\theta) \left[u(c^C(\theta)) - h(z^C(\theta),\theta) \right] dF(\theta) + \int_{\theta_C^A}^{\infty} [1-p(\theta)] \left[u(z(\theta)) - h(z(\theta),\theta) \right] dF(\theta). \end{aligned} \tag{4.26}$$

The government's budget constraint is denoted by

$$\tau^C = \int_{\theta_C^A}^{\infty} p(\theta) b \mathbb{1}\{z^C(\theta) \leq SGA\} dF(\theta) = \int_{\theta_C^A}^{\infty} p(\theta) b dF(\theta). \tag{4.27}$$

Consumption is given by

$$c^C(\theta) = \begin{cases} b + z^C(\theta), & \text{if } z^C(\theta) \leq \text{SGA} \\ z^C(\theta), & \text{if } z^C(\theta) > \text{SGA}. \end{cases} \tag{4.28}$$

The marginal applicant θ_C^A is unique and determined by

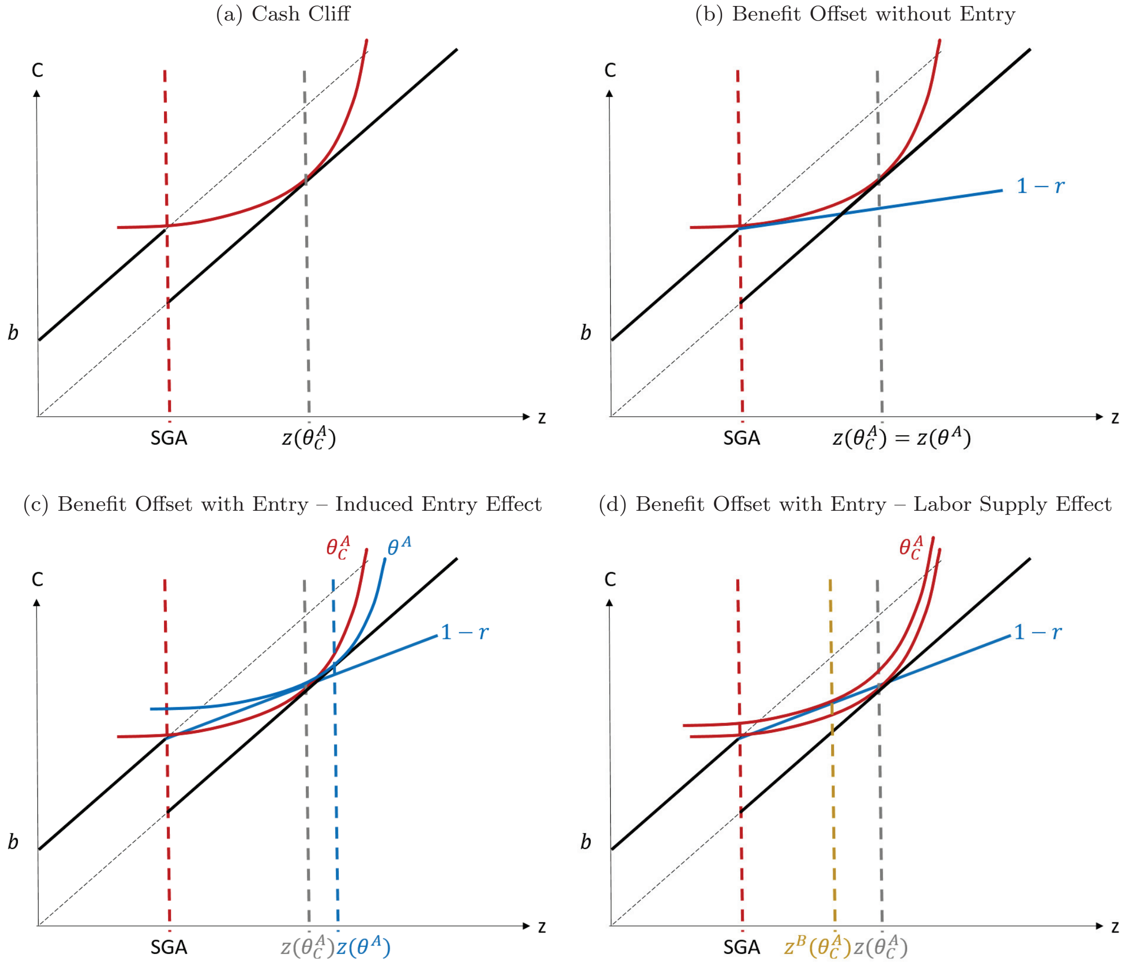
$$u(b+SGA) - h(SGA,\theta_C^A) = u(z(\theta_C^A)) - h(z(\theta_C^A),\theta_C^A), \tag{4.29}$$

where $z(\theta_C^A)$ solves

$$u'(z(\theta_C^A)) = h_z(z(\theta_C^A),\theta_C^A). \tag{4.30}$$

Proposition 3. *The introduction of a benefit offset scheme with offset r either i) has no effect at all or ii) incentivizes more labor supply of DI recipients but also induces more entry into DI. Hence, a benefit offset scheme with a positive labor supply effect always induces entry.*
(i) If $1-r \leq \bar{IK}$ where $\bar{IK}$ is the slope of the indifference curve of the marginal applicant under the cash cliff at the SGA, i.e. $\bar{IK} := \frac{h_z(SGA,\theta_C^A)}{u'(b+SGA)}$, then there is no labor supply effect and no induced entry effect of introducing a benefit offset scheme.
(ii) If $1-r > \bar{IK}$, then there is a positive labor supply effect but also a positive induced entry effect.

Figure 4.5: Induced Entry and Labor Supply Effects



Note: This figure illustrates Proposition 3. Panel 4.5c depicts the induced entry effect by showing that the marginal applicant changes. Panel 4.5d depicts the labor supply effect of the previous marginal applicant.

Proof. Proposition 3

Note that if the marginal applicant of the cash cliff scheme does not adjust her labor supply under the benefit offset scheme, then all θ-types receiving DI benefits do not adjust their labor supply either. Hence, to determine whether there is a positive labor supply effect it is sufficient to only look at the labor supply response of the marginal applicant θ_C^A.

Under the cash cliff system (b, SGA), the marginal applicant θ_C^A is determined by

$$u(b + SGA) - h(SGA, \theta_C^A) = u(z(\theta_C^A)) - h(z(\theta_C^A), \theta_C^A), \tag{4.31}$$

and thus it has to hold that

$$u(b + SGA) - h(SGA, \theta) > u(z(\theta)) - h(z(\theta), \theta), \ \forall \theta > \theta_C^A. \tag{4.32}$$

After the benefit offset scheme(b, r, SGA) is introduced, the marginal applicant under the cash cliff system θ_C^A solves

$$z^B(\theta_C^A) := \underset{z \geq SGA}{\operatorname{argmax}}\, u(c^B(\theta_C^A)) - h(z, \theta_C^A),$$

with

$$c^B(\theta_C^A) = \begin{cases} b + z^B(\theta_C^A), & \text{if } z^B(\theta_C^A) \leq SGA \\ b + SGA + (1-r)(z^B(\theta_C^A) - SGA), & \text{if } z^B(\theta_C^A) > SGA. \end{cases}$$

Hence, an interior solution with more labor supply by the marginal applicant θ_C^A solves

$$(1-r)u'(b+SGA+(1-r)(z^B(\theta_C^A)-SGA)) = h_z(z^B(\theta_C^A),\theta_C^A)$$

and therefore

$$1-r > \frac{h_z(SGA,\theta_C^A)}{u'(b+SGA)} \quad \Leftrightarrow \quad z^B(\theta_C^A) > SGA.$$

Moreover, we have no labor supply effect $z^B(\theta_C^A) = SGA$ if $1-r \leq \frac{h_z(SGA,\theta_C^A)}{u'(b+SGA)}$. If there is no labor supply effect, then the application decision is still the same as in the cash cliff regime and therefore there is no entry effect. Contrary, if there is a labor supply effect then there is a positive entry effect as well. Let us denote the marginal applicant under the benefit offset system θ^A. Suppose, $z^B(\theta_C^A) > SGA$ but $z^B(\theta_C^A) > z^B(\theta^A) \Leftrightarrow z(\theta_C^A) > z(\theta^A) \Leftrightarrow \theta_C^A < \theta^A$. Then, we have $u(b+SGA) - h(SGA,\theta^A) > u(z(\theta^A)) - h(z(\theta^A),\theta^A)$ by (4.32). ↯ Suppose $z^B(\theta_C^A) > SGA$ and $z^B(\theta_C^A) = z^B(\theta^A) \Leftrightarrow z(\theta_C^A) = z(\theta^A) \Leftrightarrow \theta_C^A = \theta^A$. Then, we have $u(b+SGA) - h(SGA,\theta_C^A) = u(z(\theta_C^A)) - h(z(\theta_C^A),\theta_C^A) = u(b+SGA+r(z^B(\theta_C^A)-SGA)) - h(z^B(\theta_C^A),\theta_C^A)$ but this only holds for $z^B(\theta_C^A) = SGA$. ↯ Hence, a positive labor supply effect $z^B(\theta_C^A) > SGA$ implies a positive entry effect $\theta_C^A > \theta^A$. □

Lemma 1. *Equivalence between benefit offset and cash cliff*
(i) There exists a benefit offset schedule (b, r_m, SGA) with $1-r_m = \frac{h_z(SGA,\theta_C^A)}{u'(b+SGA)}$, which is equivalent to the cash cliff regime (b, SGA), i.e. $\theta^A = \theta_C^A$ and $z^B(\theta) = z^C(\theta)\ \forall\theta$.
(ii) To evaluate the marginal welfare effect of a benefit offset policy, we can study a marginal change in r starting from r_m.

Proof. Lemma 1
i) The marginal applicant θ^A of the benefit offset scheme with (b, r_m, SGA) is determined by

$$u(b+SGA+(1-r_m)(\underbrace{z^B(\theta^A)-SGA}_{\equiv y(\theta^A)})) - h(z^B(\theta^A),\theta^A) = u(z(\theta^A)) - h(z(\theta^A),\theta^A). \qquad (4.33)$$

where $z^B(\theta^A)$ solves

$$(1-r_m)u'(b+SGA+(1-r_m)(z^B(\theta^A)-SGA)) = h_z(z^B(\theta^A),\theta^A) \qquad (4.34)$$

and $z(\theta^A)$ solves

$$u'(z(\theta^A)) = h_z(z(\theta^A),\theta^A) \qquad (4.35)$$

By $1-r_m := \frac{h_z(SGA,\theta_C^A)}{u'(b+SGA)}$, (4.34) holds if $\theta^A = \theta_C^A$ and $z^B(\theta^A) = SGA$. Uniqueness of the marginal applicant implies that this is the only solution.

Proof. $z^B(\theta) = z^C(\theta)\ \forall\theta$ holds, because for all individuals with $z^C(\theta) < SGA$ nothing changes. Moreover, all individuals that bunch at the earnings disregard under the cash cliff system (i.e. $\theta > \theta^A (= \theta_C^A)$ and $z^C(\theta) = SGA$) still bunch at SGA under the benefit offset regime as $(1-r_m)u'(b+SGA+(1-r_m)y(\theta)) < h_z(z^B(\theta),\theta)$.
ii) Follows immediately from i). As all outcomes are the same, welfare is the same. □

□

Lemma 2. *Marginal Applicants: (i) θ_C^A is unique and determined by*

$$u(b+SGA) - h(SGA,\theta_C^A) = u(z(\theta_C^A)) - h(z(\theta_C^A),\theta_C^A). \qquad (4.36)$$

This implies $z^C(\theta_C^A) = SGA$ and $z^C(\theta_C^A) < z(\theta_C^A)$.
(ii) θ^A is unique and determined by

$$u(b+SGA+(1-r)(z^B(\theta^A)-SGA)) - h(z^B(\theta^A),\theta^A) = u(z(\theta^A)) - h(z(\theta^A),\theta^A). \qquad (4.37)$$

where $z^B(\theta^A)$ solves

$$(1-r)u'(b+SGA+r(z^B(\theta^A)-SGA)) = h_z(z^B(\theta^A),\theta^A) \tag{4.38}$$

and $z(\theta^A)$ solves

$$u'(z(\theta^A)) = h_z(z(\theta^A),\theta^A). \tag{4.39}$$

Moreover, we have $SGA \leq z^B(\theta^A) < z_K$, where z_K is the intersection of the benefit offset and the regular budget set (i.e. $b+SGA+(1-r)(z_K-SGA) = z_K$), and $z^B(\theta^A) < z(\theta^A)$.

Proof. Lemma 2

(i) By definition

$$\theta_C^A := \inf\{\theta | u(c^C(\theta)) - h(z^C(\theta),\theta) > u(z(\theta)) - h(z(\theta),\theta)\}.$$

Suppose $z^C(\theta_C^A) > SGA$. Then, $c^C(\theta_C^A) = z^C(\theta_C^A)$ and $z^C(\theta_C^A) = z(\theta_C^A)$. Hence, $\theta_C^A \notin \{\theta | u(c_C(\theta)) - h(z_C^*(\theta),\theta) > u(z(\theta)) - h(z(\theta),\theta)\}$.↯ Suppose $z_C^*(\theta_C^A) < SGA$. Then, $\exists \varepsilon > 0$ such that $\bar{\theta} := \theta_C^A - \varepsilon < \theta_C^A$ and $z^C(\theta_C^A) < z^C(\bar{\theta}) < SGA$. Hence, $z^C(\bar{\theta})$ is the interior solution to $\max_{z\geq 0} u(b+z) - h(z,\bar{\theta})$. Therefore, $\bar{\theta} \in \{\theta | u(c^C(\theta)) - h(z^C(\theta),\theta) > u(z(\theta)) - h(z(\theta),\theta)\}$ but $\bar{\theta} < \theta_C^A$. ↯

Proof. Therefore, we must have $z^C(\theta_C^A) = SGA$ and θ_C^A is determined by

$$u(b+SGA) - h(SGA,\theta_C^A) = u(z(\theta_C^A)) - h(z(\theta_C^A),\theta_C^A).$$

Moreover, θ_C^A is unique because of single crossing of indifference curves of different θ-types (this is due to $h_{\theta z} > 0$).

(ii) In case that $z^B(\theta^A) < SGA$, the proof is analogous to i). Hence, this proof is for interior marginal applicants (i.e. $z^B(\theta^A) \geq SGA$) only. First, we show that $SGA \leq z^B(\theta^A) < z_K$. For $SGA \leq z^B(\theta^A)$, the same argument applies as in i). If we had $z^B(\theta^A) \geq z_K$, individuals could reduce labor supply and increase earnings by leaving DI.

Therefore, θ^A is determined by

$$u(b+SGA+(1-r)(z^B(\theta^A)-SGA)) - h(z^B(\theta^A),\theta^A) = u(z(\theta_B^A)) - h(z(\theta^A),\theta^A) \tag{4.40}$$

where $z^B(\theta^A)$ solves

$$(1-r)u'(b+SGA+(1-r)(z^B(\theta^A)-SGA)) = h_z(z^B(\theta^A),\theta^A) \tag{4.41}$$

and $z(\theta^A)$ solves

$$u'(z(\theta^A)) = h_z(z(\theta^A),\theta^A). \tag{4.42}$$

Now suppose θ_1 and θ_2 satisfy equations (4.40)-(4.42). Then, (4.42) immediately implies $\theta_1 = \theta_2$. Hence, θ^A is unique. □

□

Derivation of Equation (4.22). We now study the effect of moving from a cash cliff to a benefit offset program. To do so, we analyze the opposite change, i.e. moving from a benefit offset with work incentives $r < r_m$ closer to r_m being equivalent to a cash cliff scheme. This way, we can start with $r = r_m - \epsilon$ with $\epsilon > 0$ and let $\epsilon \to 0$. For all $\epsilon > 0$, we have an interior marginal applicant. The analysis in section 4.2.2 showed that, to get a hold of the welfare effect, we need to evaluate (4.20).

$$\frac{E[y(\theta)\frac{u'(c^B(\theta))-u'(w-\tau)}{u'(w-\tau)}|DI]}{E[y(\theta)|DI]} \gtreqless -\varepsilon + \mu\left(\frac{b-ry(\theta^A)}{b}\right)\frac{y(\theta^A)}{E[y(\theta)|DI]}, \tag{4.43}$$

where $y(\theta^A)$ denotes the earnings above the earnings disregard, i.e.

$$y(\theta) = \begin{cases} z^B(\theta) - SGA, & \text{if } z^B(\theta) \geq \text{SGA} \\ 0, & \text{if } z^B(\theta) < \text{SGA}. \end{cases} \tag{4.44}$$

For $r \to r_m$, we have $\theta^A \to \theta^A_C$, $y(\theta^A) \to 0$.

We can bound the numerator on the LHS with

$$\begin{aligned} \frac{u'(c^B(\theta^A)) - u'(w-\tau)}{u'(w-\tau)} E[y(\theta)|DI] &\leq E[y(\theta)\frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)}|DI] \\ &\leq \frac{u'(b+SGA) - u'(w-\tau)}{u'(w-\tau)} E[y(\theta)|DI], \end{aligned} \tag{4.45}$$

by concavity of $u()$. By the sandwich theorem, we thus have

$$\lim_{\epsilon\to 0} \frac{E[y(\theta)\frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)}|DI]}{E[y|DI]} = \frac{u'(b+SGA) - u'(w-\tau)}{u'(w-\tau)}, \tag{4.46}$$

since $\lim_{\epsilon\to 0} y(\theta^A) = 0$.

For the RHS, we have

$$\lim_{\epsilon\to 0} \left(\frac{b - ry(\theta^A)}{b}\right) = 1, \tag{4.47}$$

and

$$\frac{y(\theta^A)}{E[y(\theta)||DI]} \geq 1. \tag{4.48}$$

Note that $\frac{y(\theta^A_B)}{E[y(\theta)|DI]}$ is increasing in ϵ because

$$\frac{\partial}{\partial r}\frac{y(\theta^A)}{E[y(\theta)|DI]} = \frac{\frac{\partial y(\theta^A)}{\partial r}E[y(\theta)|DI] - \frac{\partial E[y|DI]}{\partial r}y(\theta^A)}{E[y(\theta)|DI]^2} > 0 \tag{4.49}$$

$$\leftrightarrow$$

$$\frac{\partial y(\theta^A)}{\partial r}\frac{r}{y(\theta^A)} > \frac{\partial E[y(\theta)|DI]}{\partial r}\frac{r}{E[y(\theta)|DI]} \tag{4.50}$$

$$\leftrightarrow$$

$$\varepsilon_{marginal} > \varepsilon_{average}. \tag{4.51}$$

Therefore, $\frac{y(\theta^A)}{E[y(\theta)|DI]}$ is monotonically decreasing for $r \to r_m$, and therefore

$$\lim_{\epsilon\to 0} \frac{y(\theta^A)}{E[y(\theta)|DI]} = \inf\{\frac{y(\theta^A)}{E[y(\theta)|DI]}\} = 1. \tag{4.52}$$

All together, we have

$$\frac{u'(b+SGA) - u'(w-\tau)}{u'(w-\tau)} \gtreqless -\varepsilon + \mu \tag{4.53}$$

for the marginal introduction of a benefit offset.

4.B Model Extensions

Our results from the baseline model discussed in the main part of this paper generally hold for several extensions: (1) convex preferences with single crossing (as compared to separability of consumption and disutility of work), (2) presence of application costs to the DI program,

(3) benefit substitution (presence of other welfare programs), (4) adjustment costs to changing labor supply, (5) other sources of heterogeneity, and (6) one-period structure with taxes. With exemptions, every extension discussed in this Appendix follows the same structure. First, we point out the difference between the standard case and the extension. Second, we show that the sufficient statistics formula to find the optimal offset rate r still holds. Third, we show that the sufficient statistics formula regarding an introduction of a benefit offset scheme instead of a cash cliff system still applies.

4.B.1 Convex Preferences (Non-Separability of Consumption and Disutility of Work)

All derivations for the optimal benefit offset r do not rely on the separability of consumption and disutility of work. All formulas are generally valid for any convex preferences with single crossing of indifference curves for different θ-types. A generic utility function fulfilling these conditions could be $U(\theta) = U(c(z(\theta)), z(\theta), \theta)$. All results from the main part still hold, but the notation becomes slightly more cumbersome (i.e. $u'(c)$ becomes $U_c(c, z, \theta)$, $h_z(z, \theta)$ becomes $U_z(c, z, \theta)$, and $h_\theta(z, \theta)$ becomes $U_\theta(c, z, \theta)$). The intuition for the robustness to non-separability is that our results rely on envelope conditions, i.e. that behavioral responses of individuals do not have first order welfare effects. Our results do not exploit the functional form of the utility function.

4.B.2 Application Costs

Setup

In this extension, we consider disability application costs $\psi > 0$. We only consider application costs that are low enough such that at least some individuals still apply for disability insurance (i.e. $\exists \theta^{max} \leq \infty$ s.t. $\psi = u(c^B(\theta^{max})) - h(z^B(\theta^{max}), \theta^{max}) - u(z(\theta^{max})) - h(z(\theta^{max}), \theta^{max})$). Individuals with disutility of labor θ choose their labor supply $z(\theta) \geq 0$ by maximizing

$$z(\theta) := \underset{z \geq 0}{\operatorname{argmax}}\, u(c(z)) - h(z, \theta),$$

where $c(z) = z$. Under a benefit offset scheme (b, r, SGA), individuals with disutility of labor θ choose their labor supply $z^B(\theta) \geq 0$ by maximizing

$$z^B(\theta) := \underset{z \geq 0}{\operatorname{argmax}}\, u(c^B(z)) - h(z, \theta),$$

where

$$c^B(\theta) = \begin{cases} b + z^B(\theta), & \text{if } z^B(\theta) \leq SGA, \\ b + SGA + (1-r)(z^B(\theta) - SGA), & \text{if } z^B(\theta) > SGA. \end{cases}$$

These are exactly the same as in the standard model. The only difference to the standard case is that individuals choose to apply for DI if

$$u(z(\theta)) - h(z(\theta), \theta) \leq u(c^B(\theta)) - h(z(\theta), \theta) - \frac{\psi}{p(\theta)}. \tag{4.54}$$

Note that the single crossing condition is still fulfilled as the LHS of inequality (4.54) decreases in θ while the right-hand side increases in θ. Particularly, the "relative application costs" $\psi/p(\theta)$ decrease in θ. Consequently, the unique marginal applicant is now determined by

$$u(z(\theta^A)) - h(z(\theta^A), \theta^A) = u(c^B(\theta^A)) - h(z^B(\theta^A), \theta^A) - \frac{\psi}{p(\theta^A)}, \tag{4.55}$$

$$u'(z(\theta^A)) = h_z(z(\theta^A), \theta^A), \text{ and} \tag{4.56}$$

$$(1-r)u'(c^B(\theta^A)) = h_z(z(\theta^A), \theta^A). \tag{4.57}$$

Optimal Benefit Offset r

Welfare is given by

$$\begin{aligned} W =& u(w-\tau) + \int_0^{\theta^A} u(z(\theta)) - h(z(\theta),\theta) dF(\theta) + \int_{\theta^A}^{\infty} p(\theta)[u(c^B(\theta)) - h(z^B(\theta),\theta) - \psi] dF(\theta) \\ &+ \int_{\theta^A}^{\infty} [1-p(\theta)][u(z(\theta)) - h(z(\theta),\theta) - \psi] dF(\theta). \end{aligned}$$

The government budget constraint is given by

$$\tau = \int_{\theta^A}^{\infty} p(\theta)(b - ry(\theta)) dF(\theta),$$

where y is defined as income above SGA, i.e.

$$y(\theta) = \begin{cases} z^B(\theta) - SGA, & \text{if } z^B(\theta) \geq SGA \\ 0, & \text{if } z^B(\theta) < SGA. \end{cases}$$

The welfare effect of a marginal change in the benefit offset rate r is

$$\frac{\partial W}{\partial r} = -\frac{\partial \tau}{\partial r} u'(w-\tau) - \int_{\theta^A}^{\infty} p(\theta) u'(c^B(\theta)) y(\theta) dF(\theta),$$

where

$$\begin{aligned} \frac{\partial \tau}{\partial r} =& \underbrace{-\frac{\partial \theta^A}{\partial r} f(\theta^A) p(\theta^A)}_{\text{entry effect}} \left[b - ry(\theta^A)\right] - r \int_{\theta^A}^{\infty} p(\theta) \underbrace{\frac{\partial y(\theta)}{\partial r}}_{\text{labor supply effect}} dF(\theta) \\ & \underbrace{- \int_{\theta^A}^{\infty} p(\theta) y(\theta) dF(\theta).}_{\text{mechanical costs}} \end{aligned}$$

This is equivalent to the standard case. In fact, the only difference to the standard model is the determination of the marginal applicant θ^A. We can, however, still show the equivalence of $\frac{\partial \theta^A}{\partial r} = -\frac{\partial \theta^A}{\partial b} y(\theta^A) = -\frac{\partial \theta^A}{\partial SGA} \frac{y(\theta^A)}{r}$ using equations (4.55)-(4.57), as

$$\begin{aligned} \frac{\partial \theta^A}{\partial b} &= -\frac{u'(c^B)}{h_\theta(z,\theta^A) - h_\theta(z^B,\theta^A) + \psi \frac{p'(\theta^A)}{p(\theta^A)^2}}, \\ \frac{\partial \theta^A}{\partial r} &= \frac{u'(c^B) y(\theta^A)}{h_\theta(z,\theta^A) - h_\theta(z^B,\theta^A) + \psi \frac{p'(\theta^A)}{p(\theta^A)^2}}, \text{ and} \\ \frac{\partial \theta^A}{\partial SGA} &= -\frac{u'(c^B) r}{h_\theta(z,\theta^A) - h_\theta(z^B,\theta^A) + \psi \frac{p'(\theta^A)}{p(\theta^A)^2}}. \end{aligned}$$

Hence, we also arrive at

$$\frac{E[y(\theta) \frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)} | DI]}{E[y(\theta)|DI]} \geq -\varepsilon + \mu \left(\frac{b - ry(\theta^A)}{b} \right) \frac{y(\theta^A)}{E[y(\theta)|DI]},$$

where μ is the benefit take-up elasticity with respect to b

$$\mu = \frac{\partial \int_{\theta^A}^{\infty} p(\theta) dF(\theta)}{\partial b} \frac{b}{\int_{\theta^A}^{\infty} p(\theta) dF(\theta)} = -\frac{\partial \theta^A}{\partial b} f(\theta^A) p(\theta^A) \frac{b}{\int_{\theta^A}^{\infty} p(\theta) dF(\theta)}.$$

Moving from Cash Cliff to Benefit Offset

All calculations from the main part of the paper still apply.

4.B.3 Benefit Substitution

In this subsection, we assume that all individuals have access to an unconditional welfare program (W) apart from DI. Everyone receiving benefits b^W is not allowed to supply any labor.

Optimal Benefit Offset r

There are three possible scenarios for this unconditional welfare program to interact with DI depicted in figure 4.6: (1) the unconditional benefit paid is low $b^W \leq b$ (panel 4.6a), (2) the unconditional benefit is intermediate $b^W \in (b, b^{\tilde{W}}]$ (panels 4.6b and 4.6c), and (3) the unconditional benefit is very high $b^W > b^{\tilde{W}}$ (panel 4.6d). $b^{\tilde{W}}$ is the level of unconditional income that would set the marginal applicant θ^A indifferent between working, applying to DI, and dropping out of the labor force to receive $b^{\tilde{W}}$ and is given by $u(b^{\tilde{W}}) = u(c^B(\theta^A)) - h(z^B(\theta^A), \theta^A) = u(z(\theta^A)) - h(z(\theta^A), \theta^A)$. In scenario (2), there are again two possible cases. Either the agent indifferent between W and DI with disutility of work θ^O supplies less labor than SGA/exactly SGA ($y(\theta^O) = 0$, panel 4.6b) or she supplies more ($y(\theta^O) > 0$, panel 4.6c). The scenarios and their implications for the model will be discussed in greater detail below.

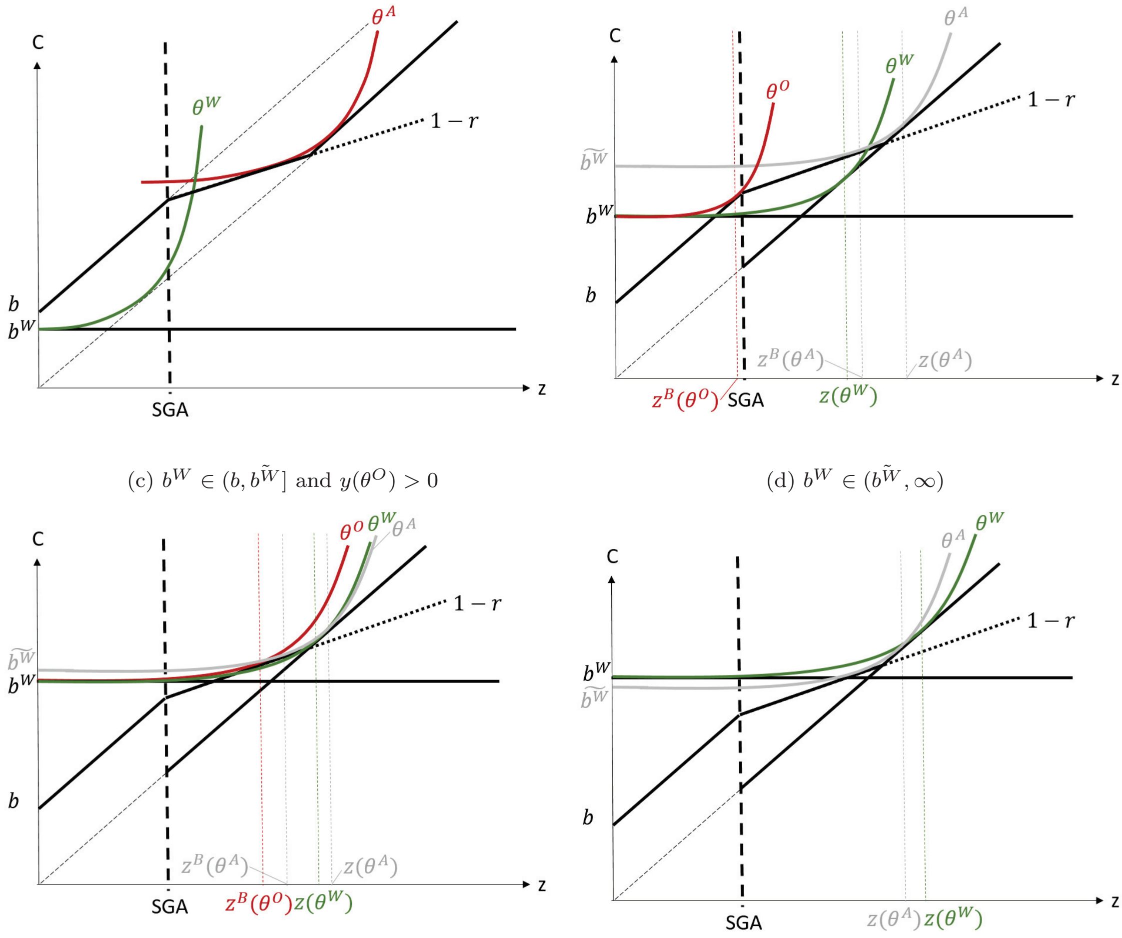
Figure 4.6: Benefit Substitution Scenarios

(a) $b^W \leq b$

(b) $b^W \in (b, b^{\tilde{W}}]$ and $y(\theta^O) = 0$

(c) $b^W \in (b, b^{\tilde{W}}]$ and $y(\theta^O) > 0$

(d) $b^W \in (b^{\tilde{W}}, \infty)$



Note: Panel 4.6a corresponds to scenario 1, panels 4.6b and 4.6c correspond to scenario 2, and panel 4.6d corresponds to scenario 3.

Scenario 1 $b^W \leq b$: First, let us assume that $b^W \leq b$. This is the empirically most relevant case. With $b^W \leq b$, individuals that have the most severe disability (high θ) have an incentive to apply for disability insurance instead of not applying to DI and receiving the benefits of W. Phrased differently, if we assume that $b < b^W$ the policy maker could increase b up to b^W without changing individuals' behavior.

Every individual with $\theta \geq \theta^W$ chooses to receive unconditional benefits b^W instead of working, where θ^W is determined by

$$u(b^W) = u(z(\theta^W)) - h(z(\theta^W), \theta^W).$$

Everything else remains as in the baseline model. By concavity of the utility function, we further know that everyone that does not supply labor, i.e. $\theta \geq \theta^W$, applies to DI. This means that $\theta^A \leq \tilde{\theta} \leq \theta^W$, where

$$u(b) = u(z(\tilde{\theta})) - h(z(\tilde{\theta}), \tilde{\theta})$$
$$u(c^B(\theta^A)) - h(z^B(\theta^A), \theta^A) = u(z(\theta^A)) - h(z(\theta^A), \theta^A).$$

Consequently, welfare is given by

$$
\begin{aligned}
W^{W1} =& u(w-\tau) + \int_0^{\theta^A} u(z(\theta)) - h(z(\theta),\theta) dF(\theta) \\
&+ \int_{\theta^A}^{\infty} p(\theta)[u(c^B(\theta)) - h(z^B(\theta),\theta) dF(\theta) \\
&+ \int_{\theta^A}^{\theta^W} (1-p(\theta))[u(z(\theta)) - h(z(\theta),\theta)] dF(\theta) \\
&+ \int_{\theta^W}^{\infty} (1-p(\theta)) u(b^W) dF(\theta).
\end{aligned}
$$

The government budget constraint is equal to

$$
\tau = \int_{\theta^A}^{\infty} p(\theta)[b - ry(\theta)] dF(\theta) + \int_{\theta^W}^{\infty} (1-p(\theta)) b^W dF(\theta).
$$

The partial derivative of welfare with respect to the offset r is

$$
\frac{\partial W^{W1}}{\partial r} = -u'(w-\tau)\frac{\partial \tau}{\partial r} - \int_{\theta^A}^{\infty} p(\theta) u'(c^B(\theta)) y(\theta) dF(\theta)
$$

with

$$
\frac{\partial \tau}{\partial r} = -\int_{\theta^A}^{\infty} p(\theta) y(\theta) dF(\theta) - \int_{\theta^A}^{\infty} p(\theta) r \frac{\partial y(\theta)}{\partial r} dF(\theta) + \frac{\partial \theta^A}{\partial r} p(\theta^A) f(\theta^A)(ry(\theta) - b).
$$

Hence, the optimality conditions are the same as in the baseline model. The only difference is that apart from b, SGA, and r the policy maker has to choose the optimal level of unconditional welfare benefits b^W. This is, however, orthogonal to the optimal benefit offset program.

Scenario 2 $b^W \in (b, b^{\tilde{W}}]$: Second, let us assume that $b^W \in (b, b^{\tilde{W}}]$. In this scenario, we have to consider three marginal agents. The first agent with θ^A is indifferent between being applying to DI with labor supply $z^B(\theta^A)$ and supplying $z(\theta^A)$ without assistance. The second agent with θ^O is indifferent between receiving unconditional welfare and being on DI with labor supply $z^B(\theta^O)$. The third agent with θ^W is indifferent between receiving unconditional welfare and supplying $z(\theta^W)$ without assistance. They are determined by the following equations

$$
u(c^B(\theta^A)) - h(z^B(\theta^A),\theta^A) = u(z(\theta^A)) - h(z(\theta^A),\theta^A), \tag{4.58}
$$

$$
u(c^B(\theta^O)) - h(z^B(\theta^O),\theta^O) = u(b^W), \text{ and} \tag{4.59}
$$

$$
u(z(\theta^W)) - h(z(\theta^W),\theta^W) = u(b^W). \tag{4.60}
$$

By $b^W \leq b^{\tilde{W}}$ and the definition of $b^{\tilde{W}}$, it follows that $u(b^W) \leq u(b^{\tilde{W}}) = u(c^B(\theta^A)) - h(z^B(\theta^A),\theta^A)$. Together with equations (4.58)-(4.60), we get $\theta^W \geq \theta^A$ and $\theta^O \geq \theta^A$. Hence, both θ^W- and θ^O-individuals would prefer applying to DI rather than working. Hence, we know that

$$
\begin{aligned}
u(z(\theta^O)) - h(z(\theta^O),\theta^O) &\leq u(c^B(\theta^O)) - h(z^B(\theta^O),\theta^O) = u(b^W) \\
&= u(z(\theta^W)) - h(z(\theta^W),\theta^W) \\
&\leq u(c^B(\theta^W)) - h(z^B(\theta^W),\theta^W),
\end{aligned}
$$

which implies that $\theta^O \geq \theta^W \geq \theta^A$. We can distinguish between four types of agents: (1) agents that drop out of the labor force to receive unconditional benefits $\theta \in [\theta^O, \infty)$, (2) agents that apply to DI and drop out of the labor force if they are rejected $\theta \in [\theta^W, \theta^O)$, (3) agents that apply to DI and work without assistance if rejected $\theta \in [\theta^A, \theta^W)$, and (4) agents that do not apply to DI and work without assistance $\theta \in [0, \theta^A)$. Welfare is given by

$$
\begin{aligned}
W^{W2} =& u(w-\tau) + \int_0^{\theta^A} u(z(\theta)) - h(z(\theta),\theta) dF(\theta) \\
&+ \int_{\theta^A}^{\theta^O} p(\theta)[u(c^B(\theta)) - h(z^B(\theta),\theta)] dF(\theta) \\
&+ \int_{\theta^A}^{\theta^W} (1-p(\theta))[u(z(\theta)) - h(z(\theta),\theta)] dF(\theta) + \int_{\theta^W}^{\theta^O} (1-p(\theta)) u(b^W) dF(\theta) \\
&+ \int_{\theta^O}^{\infty} u(b^W) dF(\theta).
\end{aligned}
$$

The government budget constraint is given by

$$
\tau = \int_{\theta^A}^{\theta^O} p(\theta)[b - ry(\theta)] dF(\theta) + \int_{\theta^W}^{\theta^O} (1-p(\theta)) b^W dF(\theta) + \int_{\theta^O}^{\infty} b^W dF(\theta).
$$

A marginal change in the offset rate r causes welfare to change according to

$$
\frac{\partial W^{W2}}{\partial r} = -u'(w-\tau)\frac{\partial \tau}{\partial r} - \int_{\theta^A}^{\theta^O} p(\theta) u'(c^B(\theta)) y(\theta) dF(\theta)
$$

with

$$
\begin{aligned}
\frac{\partial \tau}{\partial r} =& -\frac{\partial \theta^A}{\partial r} p(\theta^A) f(\theta^A)[b - ry(\theta^A)] - r\int_{\theta^A}^{\theta^O} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta) \\
&- \int_{\theta^A}^{\theta^O} p(\theta) y(\theta) dF(\theta) + \underbrace{\frac{\partial \theta^O}{\partial r} p(\theta^O) f(\theta^O)[b - ry(\theta^O) - b^W]}_{\text{program substitution effect}}.
\end{aligned}
$$

Note that the *program substitution effect* is zero if $\frac{\partial \theta^O}{\partial r} = 0$. This condition holds if $y(\theta^O) = 0$ which is equivalent to $(1-r)u'(b + SGA) \leq h_z(SGA, \theta^O)$. Otherwise, the program substitution effect is negative. A smaller benefit offset makes DI more attractive as compared to the unconditional welfare program inducing DI entry and W exit. As the costs of W are higher than those of DI, taxes can be reduced to balance the government budget.

We can rewrite the optimality condition as

$$
\begin{aligned}
\frac{\partial \tilde{W}^{W2}}{\partial r} =& \frac{\partial W^{W2}/\partial r}{u'(w-\tau)} = \frac{\partial \theta^A}{\partial r} p(\theta^A) f(\theta^A)[b - ry(\theta^A)] + r\int_{\theta^A}^{\theta^O} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta) \\
&- \int_{\theta^A}^{\theta^O} p(\theta) y(\theta) \frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)} dF(\theta) \\
&- \frac{\partial \theta^O}{\partial r} p(\theta^O) f(\theta^O)[b - ry(\theta^O) - b^W] \\
=& [\frac{\partial \theta^A}{\partial r} p(\theta^A) f(\theta^A) - \frac{\partial \theta^O}{\partial r} p(\theta^O) f(\theta^O)][b - ry(\theta^A)] \\
&- \frac{\partial \theta^O}{\partial r} p(\theta^O) f(\theta^O)[ry(\theta^A) - ry(\theta^O) - b^W] \\
&+ r\int_{\theta^A}^{\theta^O} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta) - \int_{\theta^A}^{\theta^O} p(\theta) y(\theta) \frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)} dF(\theta).
\end{aligned}
$$

Hence, welfare decreases in the offset rate r if

$$
\frac{E[y(\theta)\frac{u'(c^B(\theta)) - u'(w-\tau)}{u'(w-\tau)}|DI]}{E[y(\theta)|DI]} \geq -\varepsilon - \nu\frac{b - ry(\theta^A)}{E[y(\theta)|DI]} + \kappa\frac{ry(\theta^A) - ry(\theta^O) - b^W}{E[y(\theta)|DI]}\frac{P(DI)}{P(W)}, \qquad (4.61)
$$

where ε is the earnings elasticity of DI recipients

$$\varepsilon := \int_{\theta^A}^{\theta^O} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta) \frac{r}{\int_{\theta^A}^{\theta^O} p(\theta)y(\theta)dF(\theta)},$$

ν is the DI take-up semi-elasticity with respect to r

$$\nu := \frac{\partial[\int_{\theta^A}^{\theta^O} p(\theta)dF(\theta)]}{\partial r}\frac{1}{\int_{\theta^A}^{\theta^O} p(\theta)dF(\theta)} = [\frac{\partial\theta^O}{\partial r}p(\theta^O)f(\theta^O) - \frac{\partial\theta^A}{\partial r}p(\theta^A)f(\theta^A)]\frac{1}{\int_{\theta^A}^{\theta^O} p(\theta)dF(\theta)},$$

and κ is the W take-up semi-elasticity (program substitution) with respect to r

$$\begin{aligned}\kappa &:= \frac{\partial[\int_{\theta^W}^{\theta^O}(1-p(\theta))dF(\theta) + \int_{\theta^O}^{\infty} dF(\theta)]}{\partial r}\frac{1}{\int_{\theta^W}^{\theta^O}(1-p(\theta))dF(\theta) + \int_{\theta^O}^{\infty} dF(\theta)} \\ &= -\frac{\frac{\partial\theta^O}{\partial r}f(\theta^O)p(\theta^O)}{\int_{\theta^W}^{\theta^O}(1-p(\theta))dF(\theta) + \int_{\theta^O}^{\infty} dF(\theta)},\end{aligned}$$

and

$$\begin{aligned}P(DI) &:= \int_{\theta^A}^{\theta^O} p(\theta)dF(\theta), \text{ and} \\ P(W) &:= \int_{\theta^W}^{\theta^O}(1-p(\theta))dF(\theta) + \int_{\theta^O}^{\infty} dF(\theta).\end{aligned}$$

It can be shown that $\frac{\partial\theta^A}{\partial r} = -\frac{\partial\theta^A}{\partial b}y(\theta^A)$ and $\frac{\partial\theta^O}{\partial r} = -\frac{\partial\theta^O}{\partial b}y(\theta^O)$, allowing to rewrite condition 4.61 as

$$\begin{aligned}\frac{E[y(\theta)\frac{u'(c^B(\theta))-u'(w-\tau)}{u'(w-\tau)}|DI]}{E[y(\theta)|DI]} &\geq -\varepsilon + \mu\frac{b-ry(\theta^A)}{b}\frac{y(\theta^A)}{E[y(\theta)|DI]} \\ &\quad - \omega\frac{y(\theta^O)[b-ry(\theta^O)-b^W] - y(\theta^A)[b-ry(\theta^A)]}{bE[y(\theta)|DI]}\frac{P(DI)}{P(W)}, \qquad (4.62)\end{aligned}$$

where μ is the DI take-up elasticity with respect to b

$$\mu := \frac{\partial[\int_{\theta^A}^{\theta^O} p(\theta)dF(\theta)]}{\partial b}\frac{b}{\int_{\theta^A}^{\theta^O} p(\theta)dF(\theta)} = [\frac{\partial\theta^O}{\partial b}p(\theta^O)f(\theta^O) - \frac{\partial\theta^A}{\partial b}p(\theta^A)f(\theta^A)]\frac{b}{\int_{\theta^A}^{\theta^O} p(\theta)dF(\theta)}$$

and ω is the W take-up elasticity (program substitution) with respect to b

$$\begin{aligned}\omega &: = \frac{\partial[\int_{\theta^W}^{\theta^O}(1-p(\theta))dF(\theta) + \int_{\theta^O}^{\infty} dF(\theta)]}{\partial b}\frac{b}{\int_{\theta^W}^{\theta^O}(1-p(\theta))dF(\theta) + \int_{\theta^O}^{\infty} dF(\theta)} \\ &= -b\frac{\frac{\partial\theta^O}{\partial b}f(\theta^O)p(\theta^O)}{\int_{\theta^W}^{\theta^O}(1-p(\theta))dF(\theta) + \int_{\theta^O}^{\infty} dF(\theta)}.\end{aligned}$$

Scenario 3 $b^W > b^{\tilde{W}}$: Third, let us assume that $b^W > b^{\tilde{W}}$. Consequently, we have $u(b^W) > u(b^{\tilde{W}}) = u(c^B(\theta^A)) - h(z^B(\theta^A), \theta^A)$. This means that even the agent that is indifferent between applying to disability insurance and working prefers dropping out of the labor force over DI. In this scenario, the benefit offset does not affect welfare. Phrased differently, if the government would want to induce DI entry the offset rate r would have to be very low. Welfare is given by

$$W^{W3} = u(w-\tau) + \int_0^{\theta^W} u(z(\theta)) - h(z(\theta),\theta)dF(\theta) + \int_{\theta^W}^{\infty} u(b^W)dF(\theta).$$

The government budget constraint is given by

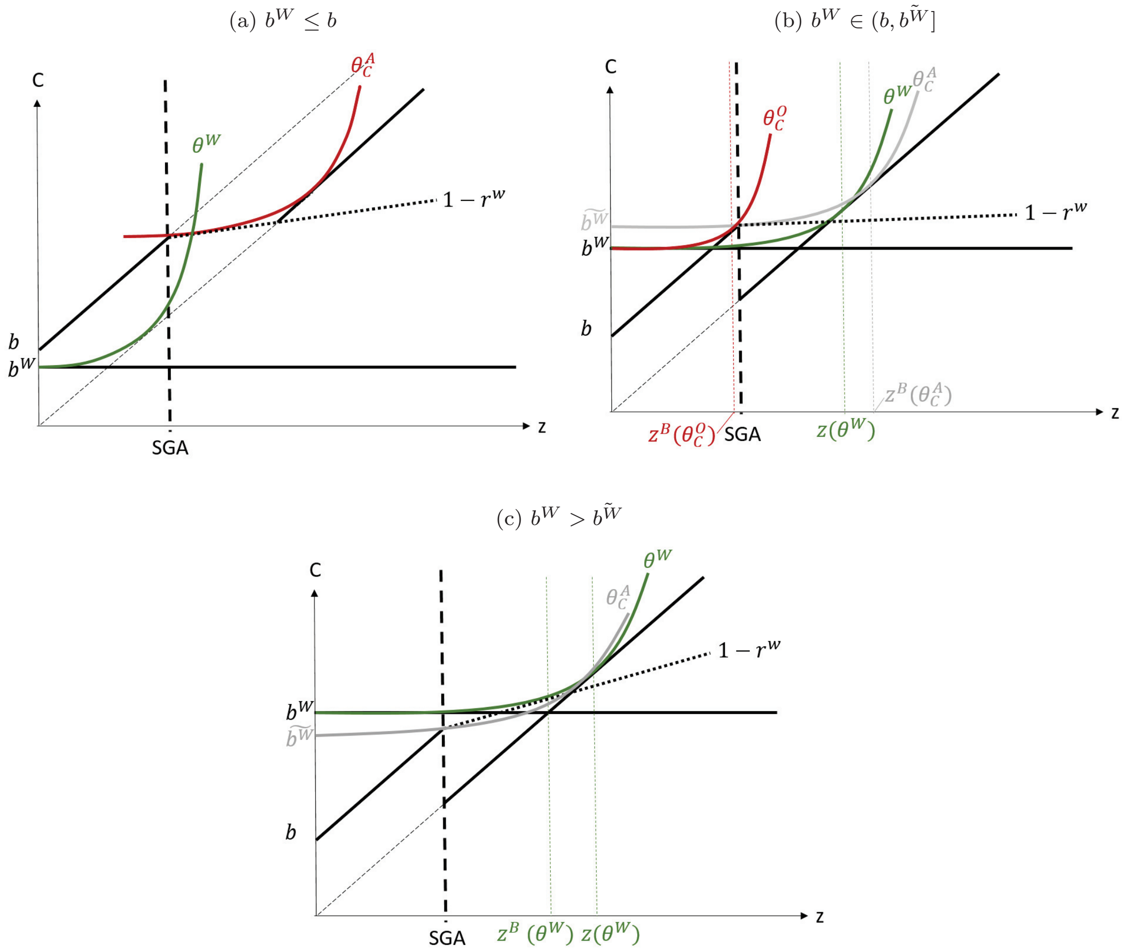
$$\tau = \int_{\theta^W}^{\infty} b^W dF(\theta).$$

Consequently, it is not possible to calculate the optimal offset rate in this scenario. The limit case of this scenario would be to decrease r until we arrive at scenario 2.

Moving from Cash Cliff to Benefit Offset

Again there are three possible scenarios for the unconditional welfare program to interact with DI moving from a cash cliff system to a benefit offset system. The three scenarios are depicted in figure 4.7. Note the differential definition of $b^{\tilde{W}}$. It is the level of unconditional income that would set the marginal applicant under the cash cliff system θ_C^A indifferent between working, applying to DI, and dropping out of the labor force to receive $b^{\tilde{W}}$ and is given by $u(b^{\tilde{W}}) = u(c^B(\theta_C^A)) - h(SGA, \theta_C^A) = u(z(\theta_C^A)) - h(z(\theta_C^A), \theta_C^A)$. Scenario 1 in this section corresponds to scenario 1 of section 4.B.3, scenario 2 corresponds to scenario 2 with $y(\theta^O) = 0$ in 4.B.3, and scenario 3 corresponds to scenario 2 with $y(\theta^O) > 0$ and scenario 3 in 4.B.3. θ^O still denotes the level of disutility of work of the individual that is indifferent between applying to DI and W. Below, the scenarios are described in detail.

Figure 4.7: Benefit Substitution – Cash Cliff to Benefit Offset Scenarios



Note: Panel 4.7a corresponds to scenario 1, panel 4.7b corresponds to scenario 2, and panel 4.7c corresponds to scenario 3. r^w is the maximum offset rate leaving the cash cliff and the benefit offset system equivalent. In scenarios 1 and 2, it is determined by $1 - r^w = \frac{h_z(SGA, \theta_C^A)}{u'(b+SGA)}$. In scenario 3, it is determined by $u(c^B(\theta^W)) - h(z^B(\theta^W), \theta^W) = u(b^W)$ with $c^B(\theta^W) = b + SGA + (1 - r^w)(z^B(\theta^W) - SGA)$.

Scenario 1 $b^W \leq b$: From the results in section 4.B.3, it follows that moving from a cash cliff to a benefit offset system in this scenario is analogous to the baseline case without the unconditional welfare program W.

Scenario 2 $b^W \in (b, b^{\tilde{W}}]$: As in section 4.B.3, we have three marginal agents to consider. The agent with θ_C^A is indifferent between being applying to DI with labor supply SGA and supplying $z(\theta_C^A)$ without assistance. The agent with θ^O is indifferent between receiving unconditional welfare and being on DI with labor supply $z^C(\theta^O)$. The last agent with θ^W is indifferent between receiving unconditional welfare and supplying $z(\theta^W)$ without assistance. They are determined by the following equations

$$u(c^C(\theta_C^A)) - h(SGA, \theta_C^A) = u(z(\theta_C^A)) - h(z(\theta_C^A), \theta_C^A), \tag{4.63}$$

$$u(c^C(\theta^O)) - h(z^C(\theta^O), \theta^O) = u(b^W), \text{ and} \tag{4.64}$$

$$u(z(\theta^W)) - h(z(\theta^W), \theta^W) = u(b^W). \tag{4.65}$$

with

$$c^C(\theta) = \begin{cases} b + z^C(\theta), & \text{if } z^C(\theta) \leq SGA, \\ z^C(\theta), & \text{if } z^B(\theta) > SGA. \end{cases}$$

By $b^W \leq b^{\tilde{W}}$ and the definition of $b^{\tilde{W}}$, it follows that $u(b^W) \leq u(b^{\tilde{W}}) = u(c^C(\theta^A_C)) - h(SGA, \theta^A_C)$. Together with equations (4.63)-(4.65), we get $\theta^W \geq \theta^A_C$ and $\theta^O \geq \theta^A_C$. Hence, both θ^W- and θ^O-individuals would prefer applying to DI rather than working. Hence, we know that

$$\begin{aligned} u(z(\theta^O)) - h(z(\theta^O), \theta^O) &\leq u(c^C(\theta^O)) - h(z^C(\theta^O), \theta^O) = u(b^W) \\ &= u(z(\theta^W)) - h(z(\theta^W), \theta^W) \\ &\leq u(c^C(\theta^W)) - h(z^C(\theta^W), \theta^W), \end{aligned}$$

which implies that $\theta^O \geq \theta^W \geq \theta^A$. We can distinguish between four types of agents: (1) agents that drop out of the labor force to receive unconditional benefits $\theta \in [\theta^O, \infty)$, (2) agents that apply to DI and drop out of the labor force if they are rejected $\theta \in [\theta^W, \theta^O)$, (3) agents that apply to DI and work without assistance if rejected $\theta \in [\theta^A, \theta^W)$, and (4) agents that do not apply to DI and work without assistance $\theta \in [0, \theta^A)$. Welfare under the cash cliff system is given by

$$\begin{aligned} W^{CW2} =& u(w - \tau^C) + \int_0^{\theta^A_C} u(z(\theta)) - h(z(\theta), \theta) dF(\theta) \\ &+ \int_{\theta^A_C}^{\theta^O} p(\theta)[u(c^C(\theta)) - h(z^C(\theta), \theta)] dF(\theta) \\ &+ \int_{\theta^A_C}^{\theta^W} (1 - p(\theta))[u(z(\theta)) - h(z(\theta), \theta)] dF(\theta) + \int_{\theta^W}^{\theta^O} (1 - p(\theta)) u(b^W) dF(\theta) \\ &+ \int_{\theta^O}^{\infty} u(b^W) dF(\theta). \end{aligned}$$

We now study the effect of moving from a cash cliff to a benefit offset program. To do so, we analyze the opposite change, i.e. moving from a benefit offset with work incentives $r < r^w$ closer to r^w being equivalent to a cash cliff scheme. This way, we can start with $r = r^w - \epsilon$ with $\epsilon > 0$ and let $\epsilon \to 0$. For all $\epsilon > 0$, we have an interior marginal applicant. Note that for $r = r^w$, $y(\theta) = 0 \,\forall\, \theta \in [\theta^A_C, \theta^O)$. Further, we know that $\lim_{r \to r^w} \theta^A = \theta^A_C$ and thus $\lim_{r \to r^w} y(\theta^A) = y(\theta^A_C)$. Let us now consider the limit case of equation 4.62. First, let us calculate the limit of the LHS of equation 4.62. We know that

$$\begin{aligned} \frac{u'(c^B(\theta^A)) - u'(w - \tau)}{u'(w - \tau)} E[y(\theta)|DI] &\leq E[y(\theta) \frac{u'(c^B(\theta)) - u'(w - \tau)}{u'(w - \tau)} |DI] \\ &\leq \frac{u'(b + SGA) - u'(w - \tau)}{u'(w - \tau)} E[y(\theta)|DI]. \end{aligned}$$

Hence, the limit of the LHS is given by

$$\lim_{r \to r^w} E[y(\theta) \frac{u'(c^B(\theta)) - u'(w - \tau)}{u'(w - \tau)} |DI] = \frac{u'(b + SGA) - u'(w - \tau)}{u'(w - \tau)}.$$

Because $\frac{y(\theta^A)}{E[y(\theta)|DI]} \geq 1$ and $y(\theta^O) = 0$, the limit of the components on the RHS are given by

$$\lim_{r \to r^w} \frac{b - ry(\theta^A)}{b} = 1,$$

$$\lim_{r \to r^w} \frac{y(\theta^A)}{E[y(\theta)|DI]} = 1, \text{ and}$$

$$\lim_{r \to r^w} \frac{\int_{\theta^A}^{\theta^O} p(\theta) dF(\theta)}{\int_{\theta^O}^{\infty} dF(\theta) + \int_{\theta^W}^{\theta^O} 1 - p(\theta) dF(\theta)} = \frac{\int_{\theta_C^A}^{\theta_C^O} p(\theta) dF(\theta)}{\int_{\theta_C^O}^{\infty} dF(\theta) + \int_{\theta^W}^{\theta_C^O} 1 - p(\theta) dF(\theta)} = \frac{P(DI)^C}{P(W)^C}.$$

Hence, the limit of the RHS is given by

$$\lim_{r \to r^w} -\varepsilon + \mu \frac{b - ry(\theta^A)}{b} \frac{y(\theta^A)}{E[y(\theta)|DI]} - \omega \frac{y(\theta^O)[b - ry(\theta^O) - b^W] - y(\theta^A)[b - ry(\theta^A)]}{bE[y(\theta)|DI]} \frac{P(DI)}{P(W)}$$
$$= -\varepsilon + \mu - \omega \frac{P(DI)^C}{P(W)^C}.$$

The condition for $\frac{\partial W^{W2}}{\partial r} \leq 0$ becomes

$$\frac{u'(b + SGA) - u'(w - \tau)}{u'(w - \tau)} \geq -\varepsilon + \mu - \omega \frac{P(DI)^C}{P(W)^C}.$$

The last term might seem counter-intuitive at first. Panel 4.7b nicely shows that the θ^O will not react to the introduction of the benefit offset system. The term's origin lies in the definition of μ, which is the DI benefit take-up elasticity with respect to b. It comprises both the reaction of the lower marginal applicant to DI θ^A and the upper marginal applicant to DI θ^O. As θ^O increases in b (more individuals prefer DI over W), we have to correct for this effect. This correction is captured by the new term $\omega \frac{P(DI)^C}{P(W)^C}$, which is the unconditional welfare benefit take-up elasticity with respect to b weighted by the fraction of individuals on DI relative to the fraction of individuals on unconditional welfare W.

Scenario 3 $b^W > b^{\tilde{W}}$: This is not an empirically relevant case as no individual will apply to DI. Thus, the hypothetical marginal applicant to the cash cliff system no longer is the marginal applicant under the maximum benefit offset system (b, r^w, SGA). Instead the marginal W receiver has to be set indifferent between DI, W, and working to arrive at the maximum offset r^w. The maximum offset is defined by $u(c^B(\theta^W)) - h(z^B(\theta^W), \theta^W) = u(b^W)$ with $c^B(\theta^W) = b + SGA + (1 - r^w)(z^B(\theta^W) - SGA)$. Rather than introducing a benefit offset scheme to the DI program in that scenario, the government could instead introduce a benefit offset or earnings exempt to the unconditional welfare program to improve labor incentives in this economy.

4.B.4 Frictions: Adjustment Costs

This extension is still work in progress. In general, one can always think of adjustment costs when changing labor supply as a particular form of heterogeneity as extensively discussed in section 4.B.5. There might be a distribution across adjustment costs in the population with some individuals that need strong incentives to change labor supply and others that have adjustment costs close to zero – the latter would correspond to individuals treated in the baseline model. Consequently, the reaction caused by changes to the DI program would just be focused in one particular part of the population. The parameters one would have to estimate, however, would still be the same. Other possibilities to incorporate adjustment costs when changing labor supply are presented in Gelber et al. (2013) or Kleven (2018a). They require non-marginal policy changes, which we did not yet include into the model.

4.B.5 Other Sources of Heterogeneity

Setup

Let us assume that there is some other source of heterogeneity affecting an individual's choice of labor supply apart from the level of disability θ. Let us call this heterogeneity $a \in (-\infty, \infty)$ and assume that there is some joint smooth distribution of θ and a denoted by $G(\theta, a)$. Let us assume that what we denoted before by $F(\theta)$ is actually the conditional distribution of θ given a corresponding to $F(\theta|a)$. Let us denote the unconditional distribution of a by $H(a)$. Hence, the choices of optimal labor supply without DI benefits and with DI benefits are given by

$$\begin{aligned} z(\theta, a) &:= \arg\max_{z \geq 0} u(z) - h(z, \theta, a), \\ z^B(\theta, a) &:= \arg\max_{z^B \geq 0} u(c^B(\theta, a)) - h(z^B, \theta, a), \end{aligned}$$

with

$$c^B(\theta, a) := \begin{cases} b + z^B(\theta, a), & \text{if } z^B(\theta, a) \leq SGA, \\ b + SGA + (1-r)y(\theta, a), & \text{if } z^B(\theta, a) > SGA, \end{cases}$$

and

$$y(\theta, a) := \begin{cases} 0, & \text{if } z^B(\theta, a) \leq SGA, \\ z^B(\theta, a) - SGA, & \text{if } z^B(\theta, a) > SGA. \end{cases}$$

Moreover, let us assume that the wage rate in the first period also potentially depends on the heterogeneity parameter a such that utility in the first period is given by $u(w(a) - \tau)$. There is a marginal DI applicant $\theta^A(a)$ for every value of the heterogeneity parameter a given by

$$u[c^B(\theta^A(a), a)] - h[z^B(\theta^A(a), a), \theta^A(a), a] = u[z(\theta^A(a), a)] - h[z(\theta^A(a), a), \theta^A(a), a].$$

Welfare is given by

$$\begin{aligned} W = \int_{-\infty}^{\infty} &\{u(w(a) - \tau) + \int_0^{\theta^A(a)} u(z(\theta, a)) - h(z(\theta, a), \theta, a) dF(\theta|a) \\ &+ \int_{\theta^A(a)}^{\infty} p(\theta, a)[u(c^B(\theta, a)) - h(z^B(\theta, a), \theta, a) dF(\theta|a) \\ &+ \int_{\theta^A(a)}^{\infty} [1 - p(\theta, a)][u(z(\theta, a)) - h(z(\theta, a), \theta, a)] dF(\theta|a)\} dH(a). \end{aligned}$$

The government budget constraint is given by

$$\tau = \int_{-\infty}^{\infty} \{\int_{\theta^A(a)}^{\infty} p(\theta, a)[b - ry(\theta, a)] dF(\theta|a)\} dH(a).$$

Optimal Benefit Offset r

A marginal change in the offset rate has a welfare effect of

$$\frac{\partial W}{\partial r} = \int_{-\infty}^{\infty} \{-\frac{\partial \tau}{\partial r} u'(w(a) - \tau) - \int_{\theta^A(a)}^{\infty} p(\theta, a) u'(c^B(\theta, a)) y(\theta, a) dF(\theta|a)\} dH(a)$$

with

$$\begin{aligned} \frac{\partial \tau}{\partial r} = \int_{-\infty}^{\infty} &\{-\frac{\partial \theta^A(a)}{\partial r} p(\theta^A(a), a) f(\theta^A(a)|a)[b - ry(\theta^A(a), a)] \\ &- \int_{\theta^A(a)}^{\infty} rp(\theta, a) \frac{\partial y(\theta, a)}{\partial r} dF(\theta|a) - \int_{\theta^A(a)}^{\infty} p(\theta, a) y(\theta, a) dF(\theta|a)\} dH(a). \end{aligned}$$

Note that $\partial\tau/\partial r$ and $E[u'(a)-\tau] := \int_{-\infty}^{\infty} u'(w(a)-\tau)dH(a)$ are independent of a. Combining everything, we get

$$\begin{aligned}
\frac{\partial W}{\partial r} = &- \int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)u'(c^B(\theta,a))y(\theta,a)dF(\theta|a)\}dH(a) \\
&+ \int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)E[u'(a)-\tau]y(\theta,a)dF(\theta|a)\}dH(a) \\
&+ E[u'(a)-\tau]\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)[b-ry(\theta^A(a),a)] \\
&+ \int_{\theta^A(a)}^{\infty} rp(\theta,a)\frac{\partial y(\theta,a)}{\partial r}dF(\theta|a)\}dH(a).
\end{aligned}$$

Dividing by $E[u'(a)-\tau]$ on both sides yields

$$\begin{aligned}
\frac{\partial\tilde{W}}{\partial r} = &- \int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} \frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}p(\theta,a)y(\theta,a)dF(\theta|a)\}dH(a) \\
&+ \int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)b\}dH(a) \\
&- \int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)ry(\theta^A(a),a)\}dH(a) \\
&+ \int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} rp(\theta,a)\frac{\partial y(\theta,a)}{\partial r}dF(\theta|a)\}dH(a).
\end{aligned} \tag{4.66}$$

Let us define the earnings elasticity by

$$\tilde{\varepsilon} := -\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)\frac{\partial y(\theta,a)}{\partial r}dF(\theta|a)\}dH(a)\frac{r}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)y(\theta,a)dF(\theta|a)\}dH(a)},$$

the benefit take-up semi-elasticity with respect to r by

$$\begin{aligned}
\tilde{\nu} :&= -\frac{\partial[\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)]}{\partial r}\frac{1}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)} \\
&= \frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)\}dH(a)}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)},
\end{aligned}$$

the benefit take-up elasticity with respect to b $\tilde{\mu}$ by

$$\begin{aligned}
\tilde{\mu} :&= \frac{\partial[\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)]}{\partial b}\frac{b}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)} \\
&= -\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial b}p(\theta^A(a),a)f(\theta^A(a)|a)\}dH(a)}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)},
\end{aligned}$$

the expected excess labor supply of DI recipients beyond SGA by

$$E[E[y(\theta,a)|DI,a]] := \frac{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)y(\theta,a)dF(\theta|a)\}dH(a)}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)},$$

and the consumption smoothing effect of changing work incentives

$$\begin{aligned}
&E[E[\frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}y(\theta,a)|DI,a]] \\
&:= \frac{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} \frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}p(\theta,a)y(\theta,a)dF(\theta|a)\}dH(a)}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)dF(\theta|a)\}dH(a)}.
\end{aligned}$$

Dividing equation (4.66) by $\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty} p(\theta,a)y(\theta,a)dF(\theta|a)\}dH(a)$ yields

$$\begin{aligned}\frac{\partial \bar{W}}{\partial r} =& -\frac{E[E[\frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}y(\theta,a)|DI,a]]}{E[E[y(\theta,a)|DI,a]]} \\ &-\tilde{\varepsilon}+\tilde{\nu}\frac{b}{E[E[y(\theta,a)|DI,a]]} \\ &-\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)ry(\theta^A(a),a)\}dH(a)}{E[E[y(\theta,a)|DI,a]]\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty}p(\theta,a)dF(\theta|a)\}dH(a)}.\end{aligned}$$

Hence, a decrease in the offset rate increases welfare (i.e. $\frac{\partial W}{\partial r}\leq 0$) whenever

$$\begin{aligned}&\frac{E[E[\frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}y(\theta,a)|DI,a]]}{E[E[y(\theta,a)|DI,a]]} \geq -\tilde{\varepsilon}+\tilde{\nu}\frac{b}{E[E[y(\theta,a)|DI,a]]} \\ &-\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)ry(\theta^A(a),a)\}dH(a)}{E[E[y(\theta,a)|DI,a]]\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty}p(\theta,a)dF(\theta|a)\}dH(a)}.\end{aligned}$$

Note that $\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)ry(\theta^A(a),a)\}dH(a)}{E[E[y(\theta,a)|DI,a]]\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty}p(\theta,a)dF(\theta|a)\}dH(a)} \in [\tilde{\nu}\frac{ry(\theta^A(a_{max}),a_{max})}{E[E[y(\theta,a)|DI,a]]},\tilde{\nu}\frac{ry(\theta^A(a_{min}),a_{min})}{E[E[y(\theta,a)|DI,a]]}]$, where a_{min} (a_{max}) is the level of a that yields the minimum (maximum) optimal excess labor supply beyond SGA of the marginal DI applicant. Consequently, we can define a sufficient and a necessary condition for $\frac{\partial W}{\partial r}\leq 0$, which are given by

$$\begin{aligned}\frac{E[E[\frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}y(\theta,a)|DI,a]]}{E[E[y(\theta,a)|DI,a]]} &\geq \underbrace{-\tilde{\varepsilon}+\tilde{\nu}\frac{b-ry(\theta^A(a_{max}),a_{max})}{E[E[y(\theta,a)|DI,a]]}}_{\text{sufficient condition}} \\ &\geq -\tilde{\varepsilon}+\tilde{\nu}\frac{b}{E[E[y(\theta,a)|a]]} \\ &\quad -\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial r}p(\theta^A(a),a)f(\theta^A(a)|a)ry(\theta^A(a),a)\}dH(a)}{E[E[y(\theta,a)|DI,a]]\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty}p(\theta,a)dF(\theta|a)\}dH(a)} \\ &\geq \underbrace{-\tilde{\varepsilon}+\tilde{\nu}\frac{b-ry(\theta^A(a_{min}),a_{min})}{E[E[y(\theta,a)|DI,a]]}}_{\text{necessary condition}} \\ &\geq -\tilde{\varepsilon}+\tilde{\nu}\frac{b}{E[E[y(\theta,a)|DI,a]]}.\end{aligned} \tag{4.67}$$

It still holds that $\frac{\partial\theta^A(a)}{\partial r} = -y(\theta^A(a),a)\frac{\partial\theta^A(a)}{\partial b}$. Hence, we can rewrite the condition for $\frac{\partial W}{\partial r}\leq 0$ as

$$\begin{aligned}&\frac{E[E[\frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}y(\theta,a)|DI,a]]}{E[E[y(\theta,a)|DI,a]]} \geq -\tilde{\varepsilon} \\ &-\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial b}y(\theta^A(a),a)p(\theta^A(a),a)f(\theta^A(a)|a)[b-ry(\theta^A(a),a)]\}dH(a)}{E[E[y(\theta,a)|DI,a]]\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty}p(\theta,a)dF(\theta|a)\}dH(a)}.\end{aligned}$$

We can bound the latter term on the RHS by

$$
\begin{aligned}
&\tilde{\mu}\frac{y(\theta^A(a_{min}),a_{min})}{E[E[y(\theta,a)|DI,a]]}\frac{b-ry(\theta^A(a_{max}),a_{max})}{b}\\
&\geq -\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial b}y(\theta^A(a),a)p(\theta^A(a),a)f(\theta^A(a)|a)[b-ry(\theta^A(a),a)]\}dH(a)}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty}p(\theta,a)dF(\theta|a)\}dH(a)E[E[y(\theta,a)|a]]}\\
&\geq \tilde{\mu}\frac{y(\theta^A(a_{min}),a_{min})}{E[E[y(\theta,a)|DI,a]]}\frac{b-ry(\theta^A(a_{max}),a_{max})}{b}.
\end{aligned}
$$

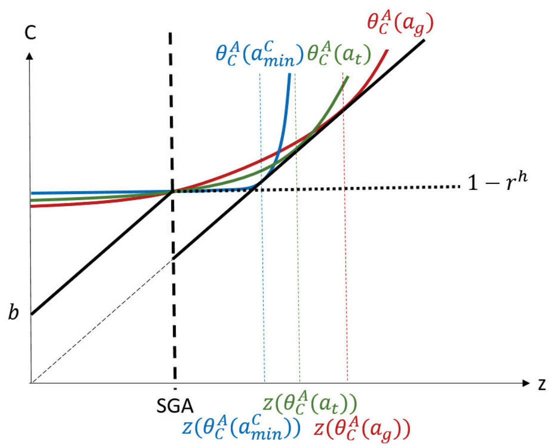
Hence, we get the sufficient and the necessary condition for $\frac{\partial W}{\partial r}\leq 0$

$$
\begin{aligned}
&\frac{E[E[\frac{u'(c^B(\theta,a))-E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}y(\theta,a)|DI,a]]}{E[E[y(\theta,a)|DI,a]]} \qquad (4.68)\\
&\underbrace{\geq -\tilde{\varepsilon}+\tilde{\mu}\frac{y(\theta^A(a_{min}),a_{min})}{E[E[y(\theta,a)|DI,a]]}\frac{b-ry(\theta^A(a_{max}),a_{max})}{b}}_{\text{sufficient condition}}\\
&\geq -\tilde{\varepsilon}-\frac{\int_{-\infty}^{\infty}\{\frac{\partial\theta^A(a)}{\partial b}y(\theta^A(a),a)p(\theta^A(a),a)f(\theta^A(a)|a)[b-ry(\theta^A(a),a)]\}dH(a)}{\int_{-\infty}^{\infty}\{\int_{\theta^A(a)}^{\infty}p(\theta,a)dF(\theta|a)\}dH(a)E[E[y(\theta,a)|a]]}\\
&\underbrace{\geq -\tilde{\varepsilon}+\tilde{\mu}\frac{y(\theta^A(a_{min}),a_{min})}{E[E[y(\theta,a)|DI,a]]}\frac{b-ry(\theta^A(a_{max}),a_{max})}{b}}_{\text{necessary condition}}.
\end{aligned}
$$

Moving from Cash Cliff to Benefit Offset

Figure 4.8: Heterogeneity – Cash Cliff to Benefit Offset

(a) Introduction of maximum benefit offset r^h.



Note: This figure illustrates the benefit offset scheme which is equivalent to the cash cliff system. The benefit offset r^h is determined by $1-r^h=\frac{h_z(SGA,\theta_C^A(a_{min}^C),a_{min}^C)}{u'(b+SGA)}$.

Let us denote the characteristic of the marginal applicant in a cash cliff system with the flattest indifference curve at SGA by a_{min}^C. Consequently, $\theta_C^A(a_{min}^C)$ is the disability level of the marginal applicant with the lowest counterfactual labor supply if working. Figure 4.8 depicts the indifference curve of this limit marginal applicant together with indifference curves of two marginal applicants with random heterogeneity characteristics a_g and a_t. Again, we can show equivalence between a cash cliff system and a limit benefit offset system. Figure 4.8 features a sketch of the maximum benefit offset rate r^h that does not affect individuals' optimal behavior as compared to the cash cliff system. The offset rate is given by the slope of the indifference curve of the limit marginal applicant $\theta_C^A(a_{min}^C)$ at SGA. This poses as a limit case of subsection 4.B.5. For $r \to r^h$, we get $\theta^A(a) \to \theta_C^A(a)\,\forall a$, $y(\theta(a), a) \to 0\,\forall a$, and thus $c^B(\theta^A(a), a) \to b + SGA\,\forall a$. The numerator on the LHS of equation 4.68 can be bounded by

$$\begin{aligned}
&\frac{u'(c^B(\theta^A(a_{max}), a_{max})) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]} E[E[y(\theta,a)|DI,a]] \\
&\geq E[\frac{u'(c^B(\theta^A(a),a)) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]} E[y(\theta,a)|DI,a]] \\
&\geq E[E[\frac{u'(c^B(\theta,a)) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]} y(\theta,a)|DI,a]] \\
&\geq E[\frac{u'(b+SGA) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]} E[y(\theta,a)|DI,a]] \\
&\geq \frac{u'(c^B(\theta^A(a_{min}), a_{min})) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]} E[E[y(\theta,a)|DI,a]].
\end{aligned}$$

By the limits defined above, we can apply the Sandwich theorem to get

$$\lim_{r \to r^h} \frac{E[E[\frac{u'(c^B(\theta,a)) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]} y(\theta,a)|DI,a]]}{E[E[y(\theta,a)|DI,a]]} = \frac{u'(b+SGA) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]}.$$

For the limit of the RHS of 4.68, we use

$$\begin{aligned}
\frac{y(\theta^A(a_{min}), a_{min})}{E[E[y(\theta,a)|a]]} &\leq 1, \\
\frac{y(\theta^A(a_{max}), a_{max})}{E[E[y(\theta,a)|a]]} &\geq 1, \\
\lim_{r \to r^h} \frac{y(\theta^A(a_{min}), a_{min})}{E[E[y(\theta,a)|a]]} &= 1, \text{ and} \\
\lim_{r \to r^h} \frac{y(\theta^A(a_{max}), a_{max})}{E[E[y(\theta,a)|a]]} &= 1.
\end{aligned}$$

Consequently, the sufficient and the necessary condition converge to the same limit for $r \to r^h$. Hence, we get that $\frac{\partial W}{\partial r} \leq 0$ if

$$\frac{u'(b+SGA) - E[u'(w(a)-\tau)]}{E[u'(w(a)-\tau)]} \geq -\tilde{\varepsilon} + \tilde{\mu},$$

where the elasticities $\tilde{\varepsilon}$ and $\tilde{\mu}$ can be estimated, as they represent the elasticities in the total population, aggregated over all heterogeneity characteristics a.

4.B.6 One Period Model with Taxes

Setup

In this addition, we show how contemporaneous taxation affects our results. Instead of a two-period model, we have a one-period model where disability hits at the beginning of the period and every individual not receiving DI benefits has to pay taxes. This means that every individual working without benefits chooses optimal labor supply $z(\theta)$ according to[11]

$$z(\theta) := \arg\max_{z\geq 0} u(z(\theta)-\tau) - h(z,\theta),$$

where τ is a lump sum per capita tax rate. Every individual on DI chooses optimal labor supply $z^B(\theta)$ according to

$$z^B(\theta) := \arg\max_{z^B\geq 0} u(c^B(\theta)) - h(z^B,\theta),$$

where

$$c^B(\theta) := \begin{cases} b + z^B(\theta), & \text{if } z^B(\theta) \leq SGA, \\ b + SGA + (1-r)y(\theta), & \text{if } z^B(\theta) > SGA, \end{cases}$$

and

$$y(\theta) = \begin{cases} z^B(\theta) - SGA, & \text{if } z^B(\theta) \geq SGA \\ 0, & \text{if } z^B(\theta) < SGA. \end{cases}$$

Moreover, everyone with disability $\theta \geq \theta^A$ applies to DI, where θ^A is given by

$$\begin{aligned} u(z(\theta^A)-\tau) - h(z(\theta^A),\theta^A) &= u(c^B(\theta^A)) - h(z^B(\theta^A),\theta^A), \\ u'(z(\theta^A)-\tau) &= h_z(z(\theta^A),\theta^A), \text{ and} \\ (1-r)u'(c^B(\theta^A)) &= h_z(z^B(\theta^A),\theta^A). \end{aligned}$$

Welfare is given by

$$\begin{aligned} W =& \int_0^{\theta^A} u(z(\theta)-\tau) - h(z(\theta),\theta)dF(\theta) + \int_{\theta^A}^{\infty} p(\theta)[u(c^B(\theta)) - h(z^B(\theta),\theta)]dF(\theta) \\ &+ \int_{\theta^A}^{\infty} [1-p(\theta)][u(z(\theta)-\tau) - h(z(\theta),\theta)]dF(\theta) \end{aligned}$$

The government budget constraint is given by

$$\begin{aligned} 0 =& \int_0^{\theta^A} \tau dF(\theta) + \int_{\theta^A}^{\infty} [1-p(\theta)]\tau dF(\theta) - \int_{\theta^A}^{\infty} p(\theta)[b - ry(\theta)]dF(\theta) \\ &\leftrightarrow \\ \tau =& \frac{\int_{\theta^A}^{\infty} p(\theta)[b-ry(\theta)]dF(\theta)}{\int_0^{\theta^A} dF(\theta) + \int_{\theta^A}^{\infty} 1-p(\theta)dF(\theta)} := \frac{\Omega}{\chi}, \end{aligned}$$

where Ω denotes the sum of payments to all DI recipients and χ denotes the fraction of tax-payers in the economy (i.e. non-DI recipients).

Optimal Benefit Offset r

A marginal change in the offset rate changes welfare according to

$$\begin{aligned} \frac{\partial W}{\partial r} =& -\int_{\theta^A}^{\infty} p(\theta)u'(c^B(\theta^A))y(\theta)dF(\theta) \\ &- \frac{\partial \tau}{\partial r}[\int_0^{\theta^A} u'(z(\theta)-\tau)dF(\theta) + \int_{\theta^A}^{\infty} [1-p(\theta)]u'(z(\theta)-\tau)dF(\theta)] \end{aligned}$$

[11] Note that we require one of two conditions to hold for this extension: either (1) $u(z(\theta)-\tau) - h(z(\theta),\theta) \geq 0 \, \forall \theta$ such that everyone paying taxes gets non-negative utility, or (2) there exists some unconditional welfare program as in section 4.B.3 scenario 1 that guarantees non-negative utility to individuals with high θ that are rejected from DI.

with

$$
\begin{aligned}
\frac{\partial\tau}{\partial r} &= -\frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta) + \int_{\theta^A}^{\infty} p(\theta)\frac{\partial y(\theta)}{\partial r} r dF(\theta) + \frac{\partial\theta^A}{\partial r} p(\theta^A)f(\theta^A)[b - ry(\theta^A)]}{\chi} \\
&\quad - \frac{\frac{\partial\theta^A}{\partial r} f(\theta^A)p(\theta^A)}{\chi}\tau \\
&= -\frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta) + r\int_{\theta^A}^{\infty} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta) + \frac{\partial\theta^A}{\partial r} p(\theta^A)f(\theta^A)[b - ry(\theta^A) + \tau]]}{\chi}.
\end{aligned}
$$

Hence, a decrease in the offset increases welfare (i.e. $\partial W/\partial r \leq 0$) whenever

$$
\begin{aligned}
\frac{\int_{\theta^A}^{\infty} p(\theta)u'(c^B(\theta^A))y(\theta)dF(\theta)}{\frac{\int_0^{\theta^A} u'(z(\theta)-\tau)dF(\theta)+\int_{\theta^A}^{\infty}[1-p(\theta)]u'(z(\theta)-\tau)dF(\theta)}{\chi}} &\geq \int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta) + r\int_{\theta^A}^{\infty} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta) \\
&\quad + \frac{\partial\theta^A}{\partial r} p(\theta^A)f(\theta^A)[b - ry(\theta^A) + \tau] \\
&\leftrightarrow \\
\frac{\frac{\int_{\theta^A}^{\infty} p(\theta)u'(c^B(\theta^A))y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}}{\frac{\int_0^{\theta^A} u'(z(\theta)-\tau)dF(\theta)+\int_{\theta^A}^{\infty}[1-p(\theta)]u'(z(\theta)-\tau)dF(\theta)}{\int_0^{\theta^A} dF(\theta)+\int_{\theta^A}^{\infty} 1-p(\theta)dF(\theta)}} &\geq \frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{p\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} \\
&\quad + \frac{r\int_{\theta^A}^{\infty} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)} \frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} \\
&\quad + \frac{\partial\theta^A}{\partial r} p(\theta^A)f(\theta^A)\frac{b - ry(\theta^A) + \tau}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} \\
&\leftrightarrow \\
\frac{\frac{E[u'(c^B(\theta))y(\theta)|DI]}{E[y(\theta)|DI]} - E[u'(z(\theta)-\tau)|^{-}DI]}{E[u'(z(\theta)-\tau)|^{-}DI]} &\geq -\varepsilon + \nu\frac{b - ry(\theta^A) + \tau}{E[y(\theta)|DI]},
\end{aligned}
\tag{4.69}
$$

where ε is the earnings elasticity

$$
\varepsilon := -\int_{\theta^A}^{\infty} p(\theta)\frac{\partial y(\theta)}{\partial r} dF(\theta)\frac{r}{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)},
$$

ν is the benefit take-up semi-elasticity with respect to r

$$
\begin{aligned}
\nu :&= -\frac{\partial\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{\partial r}\frac{1}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} \\
&= \frac{\partial\theta^A}{\partial r} p(\theta^A)f(\theta^A)\frac{1}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)},
\end{aligned}
$$

$E[u'(c^B(\theta))y(\theta)|DI]$ is given by

$$
E[u'(c^B(\theta))y(\theta)|DI] = \frac{\int_{\theta^A}^{\infty} p(\theta)u'(c^B(\theta^A))y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)},
$$

$E[u'(z(\theta)-\tau)|^{-}DI]$ is given by

$$
E[u'(z(\theta)-\tau)|^{-}DI] = \frac{\int_0^{\theta^A} u'(z(\theta)-\tau)dF(\theta) + \int_{\theta^A}^{\infty}[1-p(\theta)]u'(z(\theta)-\tau)dF(\theta)}{\int_0^{\theta^A} dF(\theta) + \int_{\theta^A}^{\infty} 1-p(\theta)dF(\theta)},
$$

and $E[y(\theta)|DI]$ is given by

$$E[y(\theta)|DI] = \frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}.$$

The condition in equation (4.69) is equivalent to the standard model apart from the tax term $\nu\frac{\tau}{E[y(\theta)|DI]}$ on the RHS. The expected difference of relative marginal utility changes of DI individuals and non-DI individuals divided by the expected excess labor supply of DI individuals are on the LHS, and the earnings elasticity and the take-up semi-elasticity with respect to r are on the RHS. The difference on the RHS stems from the changed cost effect of DI entry: the government has to pay $b - ry(\theta)^A$ to the marginal DI entrant and loses taxes τ.

From the first order condition of the marginal applicant one can derive the optimality condition $0 \overset{!}{=} F := u(c^B(\theta^A)) - h(z^B(\theta^A), \theta^A) - u(z(\theta^A) - \tau) + h(z(\theta^A), \theta^A)$. One can show that $-y(\theta^A)\frac{\partial\theta^A}{\partial b} \geq \frac{\partial\theta^A}{\partial r} \geq -E[y(\theta)|DI]\frac{\partial\theta^A}{\partial b}$. This follows from

$$\begin{aligned}
\frac{\partial\theta^A}{\partial r} &= -\frac{F_r + F_\tau\frac{\partial\tau}{\partial r}}{F_{\theta^A}} = \frac{y(\theta^A)u'(c^B(\theta^A)) - u'(z(\theta^A) - \tau)\frac{\partial\tau}{\partial r}}{h_\theta(z(\theta^A), \theta^A) - h_\theta(z^B(\theta^A), \theta^A)}, \\
\frac{\partial\theta^A}{\partial b} &= -\frac{F_b + F_\tau\frac{\partial\tau}{\partial b}}{F_{\theta^A}} = -\frac{u'(c^B(\theta^A)) + u'(z(\theta^A) - \tau)\frac{\partial\tau}{\partial b}}{h_\theta(z(\theta^A), \theta^A) - h_\theta(z^B(\theta^A), \theta^A)}, \\
\frac{\partial\tau}{\partial r} &= \frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A}\frac{\partial\theta^A}{\partial r} - \int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta) - \tau\frac{\partial\chi}{\partial\theta^A}\frac{\partial\theta^A}{\partial r}], \text{ and} \\
\frac{\partial\tau}{\partial b} &= \frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A}\frac{\partial\theta^A}{\partial b} + \int_{\theta^A}^{\infty} p(\theta)dF(\theta) - \tau\frac{\partial\chi}{\partial\theta^A}\frac{\partial\theta^A}{\partial b}].
\end{aligned}$$

Combining the equations yields

$$\begin{aligned}
\frac{\partial\theta^A}{\partial r} = -\frac{F_r + F_\tau\frac{\partial\tau}{\partial r}}{F_{\theta^A}} &= -\frac{F_r}{F_{\theta^A}} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A}\frac{\partial\theta^A}{\partial r} - \int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta) - \tau\frac{\partial\chi}{\partial\theta^A}\frac{\partial\theta^A}{\partial r}] \\
&= -\frac{F_r}{F_{\theta^A}} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]\frac{\partial\theta^A}{\partial r} + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta) \\
&\leftrightarrow \\
\frac{\partial\theta^A}{\partial r} &= \frac{-\frac{F_r}{F_{\theta^A}} + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{1 + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]} \text{ and} \\
\frac{\partial\theta^A}{\partial b} = -\frac{F_b + F_\tau\frac{\partial\tau}{\partial b}}{F_{\theta^A}} &= -\frac{F_b}{F_{\theta^A}} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A}\frac{\partial\theta^A}{\partial b} + \int_{\theta^A}^{\infty} p(\theta)dF(\theta) - \tau\frac{\partial\chi}{\partial\theta^A}\frac{\partial\theta^A}{\partial b}] \\
&= -\frac{F_b}{F_{\theta^A}} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]\frac{\partial\theta^A}{\partial b} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)dF(\theta) \\
&\leftrightarrow \\
\frac{\partial\theta^A}{\partial b} &= \frac{-\frac{F_b}{F_{\theta^A}} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{1 + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]}.
\end{aligned}$$

We know that $\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta) \leq y(\theta^A)\int_{\theta^A}^{\infty} p(\theta)dF(\theta)$ as $y(\theta^A) \geq y(\theta)\ \forall\theta \geq \theta^A$, $F_b \geq 0$, and $F_{\theta^A} \geq 0$. Further, we know that $\frac{F_r}{F_{\theta^A}} = -\frac{F_b}{F_{\theta^A}}y(\theta^A)$. Hence, it holds that

$$\begin{aligned}
\frac{\partial\theta^A}{\partial r} &= \frac{-\frac{F_r}{F_{\theta^A}} + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]} \\
&= \frac{\frac{F_b}{F_{\theta^A}}y(\theta^A) + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]} \\
&\leq \frac{\frac{F_b}{F_{\theta^A}}y(\theta^A) + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}y(\theta^A)\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]} \\
&= -\frac{-\frac{F_b}{F_{\theta^A}} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]}y(\theta^A) \\
&= -\frac{\partial\theta^A}{\partial b}y(\theta^A).
\end{aligned}$$

Moreover, it follows that

$$\begin{aligned}
\frac{\partial\theta^A}{\partial r} &= \frac{\frac{F_b}{F_{\theta^A}}y(\theta^A) + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]} \\
&\geq \frac{\frac{F_b}{F_{\theta^A}}\frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]} \\
&= \frac{\frac{F_b}{F_{\theta^A}}\frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} + \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)dF(\theta)\frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]} \\
&= -\frac{-\frac{F_b}{F_{\theta^A}} - \frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{1+\frac{F_\tau}{F_{\theta^A}}\frac{1}{\chi}[\frac{\partial\Omega}{\partial\theta^A} - \tau\frac{\partial\chi}{\partial\theta^A}]}\frac{\int_{\theta^A}^{\infty} p(\theta)y(\theta)dF(\theta)}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} \\
&= -\frac{\partial\theta^A}{\partial b}E[y(\theta)|DI].
\end{aligned}$$

From $-y(\theta^A)\frac{\partial\theta^A}{\partial b} \geq \frac{\partial\theta^A}{\partial r} \geq -E[y(\theta)|DI]\frac{\partial\theta^A}{\partial b}$, we learn that $\mu\frac{E[y(\theta)|DI]}{b} \leq \nu \leq \mu\frac{y(\theta^A)}{b}$, where μ is the benefit take-up elasticity with respect to b

$$\mu := \frac{\partial\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}{\partial b}\frac{b}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)} = -\frac{\partial\theta^A}{\partial b}p(\theta^A)f(\theta^A)\frac{b}{\int_{\theta^A}^{\infty} p(\theta)dF(\theta)}.$$

We can insert these bounds into equation (4.69) to get a sufficient condition for $\frac{\partial W}{\partial r} \leq 0$

$$\frac{\frac{E[u'(c^B(\theta))y(\theta)|DI]}{E[y(\theta)|DI]} - E[u'(z(\theta)-\tau)|^{-}DI]}{E[u'(z(\theta)-\tau)|^{-}DI]} \geq -\varepsilon + \mu\frac{b - ry(\theta^A) + \tau}{b}\frac{y(\theta^A)}{E[y(\theta)|DI]}, \tag{4.70}$$

and a necessary condition for $\frac{\partial W}{\partial r} \leq 0$

$$\frac{\frac{E[u'(c^B(\theta))y(\theta)|DI]}{E[y(\theta)|DI]} - E[u'(z(\theta)-\tau)|^{-}DI]}{E[u'(z(\theta)-\tau)|^{-}DI]} \geq -\varepsilon + \mu\frac{b - ry(\theta^A) + \tau}{b}. \tag{4.71}$$

Moving from Cash Cliff to Benefit Offset

Note that lump sum taxes under the cash cliff system are given by $\tau = \frac{\int_{\theta^A}^{\infty} p(\theta) b dF(\theta)}{\int_0^{\infty} dF(\theta) + \int_{\theta^A}^{\infty} [1-p(\theta)] dF(\theta)} = b\frac{P(DI)}{1-P(DI)}$. Let us define r^O as the maximum offset rate that makes the cash cliff and the benefit offset systems equivalent. It is determined by $1 - r^O = \frac{h_z(SGA, \theta_C^A)}{u'(b+SGA)}$. For $r \to r^O$, it holds that $\theta^A \to \theta_C^A$ and $y(\theta^A) \to 0$. Consequently, the LHS of equations 4.70 and 4.71 becomes

$$\lim_{r \to r^O} \frac{\frac{E[u'(c^B(\theta) y(\theta)|DI]}{E[y(\theta)|DI]} - E[u'(z(\theta)-\tau)|^- DI]}{E[u'(z(\theta)-\tau)|^- DI]} = \frac{E[u'(c^B(\theta))|DI] - E[u'(z(\theta)-\tau)|^- DI]}{E[u'(z(\theta)-\tau)|^- DI]}$$

by the sandwich theorem (see the baseline model and the previous additions). Moreover, it holds that

$$\lim_{r \to r^O} \frac{b - ry(\theta^A) + \tau}{b} = \frac{b+\tau}{b} = \frac{b + b\frac{P(DI)}{1-P(DI)}}{b} = \frac{1}{1-P(DI)}, \text{ and.}$$

$$\lim_{r \to r^O} \frac{y(\theta^A)}{E[y(\theta)|DI]} = 1.$$

Hence, the conditions in equations 4.70 and 4.71 have the same limit. It follow that $\frac{\partial W}{\partial r} \leq 0$ whenever

$$\frac{E[u'(c^B(\theta))|DI] - E[u'(z(\theta)-\tau)|^- DI]}{E[u'(z(\theta)-\tau)|^- DI]} \geq -\varepsilon + \mu \frac{1}{1-P(DI)}.$$

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